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I. CEREAL HAY PRODUCTION IN CALIFORNIA

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II. FEEDING TRIALS WITH CEREAL HAYS

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CEREAL HAY PRODUCTION IN CALIFORNIA

GEO. W. HENDRY

ECONOMIC IMPORTANCE

The cereals have long been of particular interest on the Pacific Coast because of the extensive use made of them for hay production. West of the Rocky Mountains they constitute about one-half of all the hay grown, and in California the acreage of small grains cut for hay is, roughly, equivalent to one-half of the combined acreage of barley, wheat, oats, and rye harvested for grain. The comparative magnitude of the hay industry in California is shown by the crop report[1] for 1923, which gives the total value of the California tame hay crop, including alfalfa, for 1923, as $73,752,000, or an amount somewhat larger than that reported for the value of the orange, lemon, pear, apricot, almond, plum, and olive crops combined. Alfalfa occupied about one-half the hay acreage of the state that year. Cereal hay is unquestionably the most widely distributed field crop in California. The census report[2] for 1919 credits every California county, excepting Alpine and San Francisco, with a cereal hay acreage, and it is presumed that upon closer examination, even these would be found to have contributed their quota. Two regions lead in grain hay production—the Great Valley of California, and the hill lands of the Coast Range counties. That portion which originates in the Great Valley is of less importance and inferior in quality, and constitutes not more than 20 per cent of the total crop in normal seasons. It is, in reality, only a by-product of the grain industry, the output of which fluctuates greatly from year to year, and becomes largest in seasons unfavorable for grain production. In this region, too, it is the practice to mow harvest lanes of from eight to twenty-five feet in width completely around each grain field several weeks before the harvest, in order to admit the harvester on its first round. By this practice some 20,000 acres of standing grain are annually converted into hay (fig. 6).

The cereal hay belt of the Coast Range, on the other hand is quite distinct from, and has little in common with, the interior grain producing areas. Here the production of cereal hays, in conjunction with stock raising, is the dominant agricultural industry, and all

[1] California Crop Report, 1923. California Coöperative Crop Reporting Service, Special Publication No. 43: 6, Sacramento, Calif. 1924.

[2] Fourteenth Census of the United States: 1920. Agriculture: California. pp. 25–30.

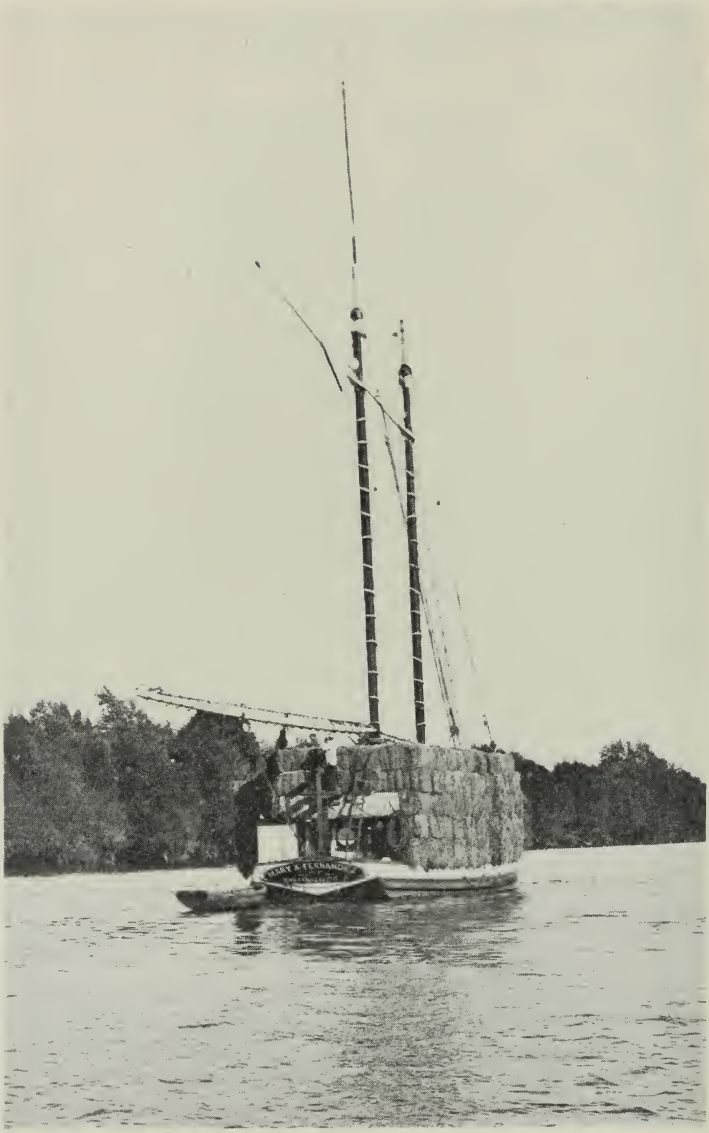

Fig. 1.—Hay schooner on the Sacramento River. The great system of waterways tributary to the bay of San Francisco provides cheap transportation for the bulky hay crop from the principal areas of origin to the terminal market. Many wholesale dealers own and operate hay schooners or barges of from 75 to 100 tons capacity, which ply between San Francisco and the producing sections of the Sacramento and San Joaquin valley, and the island districts of Marin, Sonoma, and Napa counties, as far north as Petaluma.

of the conditions necessary for the production of cereal hay of high quality are fulfilled in a very perfect manner. This area embraces a broad belt of rolling hills, known as the Coast Range, lying between the interior valleys and the sea, and extending from Sonoma County on the north to the Mexican boundary, 550 miles to the south (figs. 2, 3, 5, 7, and 14). Much of this region is too mountainous for cultivation, but is intersected throughout by an intricate system of fertile and intensively cultivated valleys, and it is upon the smoothly rounded low foothills which invariably surround these valleys that the cereal hays are produced.

Census data indicate that ten of the twelve leading cereal hay producing counties of California, each of which harvested above 32,000 acres in 1919, were situated within this area (table 1), and that the two which were not, Tulare and San Joaquin, were the two leading counties in wheat *grain* production that year, and became prominent as hay producers because of the threatened failure of the grain crop and the consequent conversion of an unusually large proportion of wheat acreage into hay. The figures, from the census report, are as follows:

TABLE 1

Leading Cereal Hay Producing Counties

County	Acres of Cereal Hay, 1919
Los Angeles	90,257
San Diego	59,658
Monterey	56,966
Alameda	48,268
San Luis Obispo	45,270
Sonoma	44,652
Contra Costa	44,347
Tulare	40,340
Santa Barbara	36,178
Riverside	34,300
San Joaquin	34,082
Santa Clara	32,882

The reasons for this preëminence of graminaceous hays in the coast counties are mainly climatic and topographic, for although the soils are generally fertile enough to support more profitable crops, the rainfall, which occurs only during the winter months, is insufficient to tide summer field crops and perennial fruits and forage crops over the summer drought, and this, coupled with the abrupt contours of the hills (figs. 3 and 5), too steep for irrigation development, limits the cropping possibilities to quick growing winter annuals, such as the cereals, which mature early in the spring, and do not require irrigation.

But it is very apparent that the full agricultural productivity of these hill lands has not yet been realized, for there are other quick growing, early maturing winter annuals, such as peas, rape, and turnips, which under careful culture would doubtless succeed in many parts of the area. Peas, especially, if harvested in the green state for canning, offer both feed and cash crop possibilities. Then there are the more drought-resistant summer annuals, such as Blackeye beans and the sorghums, which have already succeeded in the warmer interior districts of the Coast Range in a small way, and would respond

Fig. 2.—Typical scene in Marin County, north of San Francisco. The cereal hay belt of California extends through the rolling hill lands of the Coast Range from Sonoma County 550 miles southward to Mexico.

well to the application of intensive dry-farming methods such as are practiced in the Lima bean belt of the southern coast counties.

Even under the most careful culture, however, it would be futile to expect these lands to equal the level valley soils in productivity, and it is doubtful if these crops could be grown profitably at present prices. Yet, yields can be obtained which would be profitable at higher prices such as those ruling during the war, which led to the successful extension of the bean acreage of southern California well up into the hay and grazing areas of the hill lands.

Finally, there is the possibility that the stock carrrying capacity of these dry hill lands may eventually be greatly augmented through the introduction of the drought-resistant perennial grasses. At present the native pasturage consists almost entirely of annual grasses, which

grow only during the moist season, and depend entirely upon their seed for a hazardous existence from year to year. Already encouraging advances have been made in this direction through the introduction of perennial drought-resisting grasses, and the awakening interest in questions of range management augurs well for the future.

Today, the cereal hay belt of California constitutes a great reservoir of potential agricultural wealth, sparsely populated, and the last great undeveloped arable region of the state capable of intensive development.

UTILIZATION OF CEREAL HAYS

Fully 90 per cent of the cereal hay crop of California is fed in the localities where it is produced. Indeed, in years of scarcity, such as 1924, many of the exporting districts are forced to consume their entire output. Of the cultivated grain hays, about 80 per cent is usually fed to horses,* 10 per cent to stock cattle and sheep and 10 per cent to dairy cattle. Of the wild grain hays, consisting of volunteer wild oats and bur-clover and designated by the trade as stock hays, about 40 per cent is fed to horses, 40 per cent to stock cattle and sheep, and 20 per cent to dairy cattle. The surplus above local feeding requirements, amounting to about 100,000 tons, is "put up" in large five-wired bales and shipped by rail, truck, or boat (fig. 1) to the two primary markets of San Francisco and Los Angeles, as distributing centers. Each of these now takes from 40,000 to 60,000 tons annually, but as recently as 1904, San Francisco alone, and exclusive of her export trade, required 125,000 tons for the sustenance of draft and driving horses maintained within the city. Formerly there was a thriving retail hay trade in San Francisco, and a daily hay auction of arrivals at the railroad yards, but these have now been abandoned. However, the decrease in city demands brought about through rapid progress in motor transportation, has been partly compensated by the growth of interior markets, following more intensive orcharding and stock feeding operations, so that the cereal hay acreage has been substantially maintained, new acreage constantly replacing that turned to other uses.

The principal export trade in cereal hays centers about San Francisco Bay, and consists mainly of consignments for U. S. Army mules and horses in Hawaii and the Philippines. In 1923, the Quartermaster Section of the War Department in San Francisco

* There were 519,000 horses and mules remaining in California in 1920, each of which consumed about two tons of grain hay, thereby accounting for about 80 per cent of the 1,296,800-ton crop reported for 1919.

purchased and shipped 8000 tons of cereal hay to Manila, and 5000 tons to Honolulu, all of which originated in districts tributary to San Francisco and principally in the Livermore and Pleasanton districts of Alameda County, and the Reclamation district of Sonoma County. It consisted of red oats, wheat, and stock hays, mixed before shipment with one-third alfalfa, by weight. This is about the usual amount exported by water for Army use, but in 1924, because of a hay shortage in California, a part of the export requirement was met by shipments from the northwest. It is also significant that the Army authorities in the Philippines are now (1925) endeavoring to produce hay rather than to depend upon the United States for their entire supply. Small quantities of cereal hay are also shipped by the War Department to Panama, and to Tientsin, China; and about once in a decade market conditions become favorable for the shipment of California hay to Australia and South American ports, and considerable quantities have been disposed of in this way. In 1915, some 40,000 tons of Californian hay was shipped to Australia. Small quantities are also sent to Hawaii for the horses and mules on the sugar and pineapple plantations.

All hay entering the marine export trade is re-baled and tightly compressed, by a method differing from that employed at Atlantic seaports. Instead of placing whole bales in the presses and reducing their volume by combining two or more into one compact bale, the hay is taken from the original bale and run over a revolving cylinder, which pulls it apart. This loose hay is then fed into a heavy perpetual type press, which compresses it to 14 inches by 18 inches. Crosshead bale ties are used, 8 or 9 feet in length, giving bales of even length containing about 6 cubic feet, and varying from 50 to 70 cubic feet per ton. By this method hays of different grades may be mixed and combined in desired proportions, and alfalfa mixed with grain hays for army use.

Hay shipments by rail to eastern states are impracticable because of prohibitive freight rates over the mountains, except in the special case of choice lots of red oat hay for racehorse feeding. In 1924 the transportation rates by various routes from San Francisco to New York were as follows:

By rail, minimum carload weight 12 tons, $30 per ton.

By rail, minimum carload weight 25 tons, $25 per ton.

By rail to Gulf, thence steamer to New York, minimum 25 tons, $15.50 per ton.

By water, via Panama Canal, $8 to $10 per ton.

These freight charges in most cases exceed the value of the product, although the $8 rate via the Panama Canal has made it possible to ship high-grade alfalfa, in tightly compressed bales, from San Francisco and Puget Sound to Atlantic ports at a profit, and such hay has brought a premium of from $3 to $4 a ton over the darker-colored eastern alfalfa when disposed of at auction. An ever-increasing amount of high-grade Californian alfalfa is finding an outlet through this new market.

Fig. 3.—Red oat hay in the El Jaro Valley in southwestern Santa Barbara County. Typical landscape in the southern part of the cereal hay belt of California.

Eastern consumers, however, are unacquainted with the feeding qualities of Californian *cereal* hays, and have been reluctant to give them a trial, except in the special case of racehorse feeding, already mentioned. Before 1909, it was the custom of eastern racing stables to winter in California in order to profit by continuous out-of-door exercise and green feed, and at first they brought fancy timothy hay with them; but they soon became familiar with the merits of oat hay, and such noted trainers as Simpson, Hickock, Marvin, Goldsmith, and Salisbury became so thoroughly convinced that it stimulated greater spirit and stamina in their horses that they began shipping it east for the racing season, and even to England. Professor W. A. Henry, the nutrition specialist of Wisconsin, after his visit to California in 1892, remarked that the speed and draft horses of California should be superior to any in America, both because of climatic advantages, with green feed all the year, and because of the quality of the hay, which is freer from dust, mildew or mold, than eastern hays.

In 1909, California Assembly Bill No. 63, known as the Otis-Walker Anti-Racetrack Bill, became a law (Section 337*a* of the Penal Code of the State of California). This statute did not prohibit horse-racing, but it did prohibit book-making and pool-selling in conjunction with horse racing, and this restriction so decreased the popularity and attendance at the sport that racing became unprofitable and, even with a raise in the price of admission to $2, expenses could not be met. In consequence, the tracks were closed and the racing stables moved to eastern centers having no prohibitive restrictions. Californian red oat hay, however, is still as highly esteemed by racehorse trainers, and about 1000 tons from Alameda, San Benito, and Napa Counties are consigned each year for distribution among the racing centers in New York, Ohio, Maryland, Kentucky, Louisiana, and Mexico.

AREAS OF PRODUCTION

The different kinds of grain hay are preferred in different districts according to their real or supposed suitability to the soil and climate and to local feeding requirements and markets. The range of soils and climates in California is very wide, and yet for each locality in the state one or more varieties of the four cereals have been found well adapted.

Barley Hay.—Barley, because of its special adaptation to semi-arid climates, is the most generally suitable to California (fig. 4). It is the prevailing cereal upon the floor of the Great Valley, and also predominates in the interior districts of southern California. It does not thrive, however, in the cooler, more humid, coast districts, and is replaced by rye in the mountain valleys of the north, and by oats in the foothill sections of the Sierras, and in the humid coast regions of northern and central California. There is some slight production of barley hay in the mountain valleys, particularly about the logging camps, to provide feed for work stock, for which purpose it is especially esteemed; but this is only an insignificant amount compared with that produced in the larger agricultural areas. The principal barley hay producing areas of California are in the San Joaquin and Sacramento Valleys; the western portions of Contra Costa and Alameda Counties, including the Byron, Brentwood, Altamont, and Mountain-house districts; the Gonzales and Greenfield districts in Monterey County; the San Juan, Tres Pinos, Paicines and Panoche districts in San Benito County; the southern valleys of San Luis Obispo County; the Santa Maria and Los Alamos Valleys in Santa Barbara County; the Ojai, Santa Ana, Fillmore, Santa

Paula, Moorpark, Simi, Conejo, and Camarillo districts in Ventura County; the Pomona and Walnut sections in southeastern Los Angeles County; the El Toro and Capistrano districts in Orange County; the Oceanside, Fallbrook, Valley Center, Ramona, and Jamul districts in San Diego County; the Beaumont, Morena, Perris, San Jacinto, Winchester, and Diamond Valley districts in Riverside County; and in practically all of the arable portions of Imperial and San Bernardino Counties. In addition to this, small patches are to be found in practically all of the mountain counties of northern and eastern California, and in the Coast Range valleys north of San Francisco, such as Round Valley, in Mendocino County; Lower Lake and Middletown in Lake County; and Pope, Berryessa, Capell, and Wooden Valleys in eastern Napa County.

Wheat Hay.—The distribution of wheat hay in California resembles that of barley (fig. 4), but differs from it in these respects: Wheat is less drought-resistant than barley and consequently less utilized in the more arid of the interior districts. Its production is more restricted to heavier textured soils and to regions of greater precipitation. Wheat, moreover, possesses greater winter hardiness, and is more generally planted than barley in the elevated valleys of the north. Barley is less valuable than wheat as a hay crop, and consequently does not compete strongly with wheat in regions where the two produce equally well. Barley hay is often produced to satisfy local feeding requirements in lieu of something better, while wheat, because of its market popularity, is often produced in surplus quantities, especially for market consumption. The Altamont, Pleasanton, Livermore, and Amador sections of Alameda and Contra Costa counties excel in the production of wheat hay of high quality, and produce exportable surpluses. Similarly, the Hollister, Tres Pinos, San Benito, and Bitter Water regions of San Benito County are, in normal years, exporters of fine grades of wheat hay, and the Antelope Valley in Los Angeles County is also a surplus wheat hay region.

Other less prominent wheat hay districts are found in the Montezuma hills region of Solano County; the San Lucas, San Ardo, Lockwood, Priest Valley, Hall Valley, Indian Valley, and Parkfield districts of Monterey County; the Santa Maria and Los Alamos Valley districts of Santa Barbara County; the El Toro and Capistrano districts of Orange County; and in the Fallbrook, Valley Center, and Ramona districts of San Diego County. In the north, small quantities of wheat hay originate in the Scott and Shasta Valleys of Siskiyou County, and in the Cow Creek and Fall River Valleys of Shasta County. There are also plantings scattered through the Big Valley,

Lower Lake and Middletown districts of Lake County; the Pope, Berryessa, Capell and Wooden Valleys in Napa County; and in southern Sonoma and Marin counties. In addition to these there is a sparse belt of wheat hay, 175 miles in length, extending along the Sierra foothills at an elevation of from 1000 to 3500 feet, from Plumas County on the north to Madera County on the south.

Oat Hay.—Owing to dissimilarity of climatic requirements, the distribution of oat hay in California is entirely different from that of either barley or wheat (fig. 4). Oats require a moist atmosphere, when the soil is dry and porous, or a moist, deep soil when the climate is dry and warm. When, however, both the soil and climate are dry, as often happens in the great interior valley of California, oats are less advantageously cultivated, and the crop becomes scanty in both hay and grain. On the other hand, where both soil and climate are moist, as in the coast valleys of the north, an excessively rank, coarse growth of straw is obtained, generally at the expense of hay quality, and nearly always at the expense of grain production. In the intermediate climate of the central coast, however, from Sonoma to San Luis Obispo counties, particularly in the valleys on the ocean side of the Coast Range, oats grow to prefection, and here much of the oat hay and seed of the state originate.

Moreover, the wide range of soils upon which oats thrive, and the comparatively low temperature under which they come to maturity, have rendered them well adapted to cultivation at high altitudes in northern California, especially for spring planting in localities having severe winter climates (fig. 12). Hardy winter varieties of rye and wheat are the only cereals capable of surviving fall planting in such situations.

Skirting the coast of northern and central California, from the Oregon line to Point Conception in Santa Barbara County, is a narrow ribbon of coastal plain and small valleys, given over mainly to dairying (fig. 7), and the conditions here are particularly favorable for producing a vigorous oat or oat and vetch hay crop. The climate is cool, and the rainfall high, reaching a maximum annual mean of 60 inches in the extreme north. This region, particularly the southern part, also produces large quantities of oats for seed. The largest surplus production of oat hay occurs in a region adjoining and immediately north of San Pablo Bay, including a crescent-shaped area extending from Ignacio, in Marin County, to Vallejo, in Solano County, embracing the flat lands and islands in the lower Petaluma, Sonoma, and Napa valleys. Red oat hay production dominates the agriculture of this extensive region, which grows from 30,000

to 40,000 acres, exclusive of about 10,000 acres on the adobe flats in the Cotati district south of Petaluma. This area is intersected by a network of canals, which afford cheap transportation for the bulky hay crop to the San Francisco market. Some of the principal districts of the region are those about Ignacio, Reclamation, Tubbs Island, Islands No. 1 and 2, Knights Island, and Slaughterhouse Point.

San Benito County with about 8000 acres of oat hay, principally from the San Juan, Hollister, and Tres Pinos districts, and the Livermore Valley in Alameda County, are other well-known centers of production of market oat hay of high quality. In the southern part of the state oat hay is shipped from the Walnut district in Los Angeles County, and there is some local production throughout the coast valleys of southern California. Oat hay is produced in the irrigated interior districts of the entire state. There is also an irregular foothill oat hay belt, situated at an elevation of about 1000 to 4000 feet, extending through portions of twelve counties on the east side of the Great Valley, from Plumas County on the north to Madera County on the south, but cereal hay is grown here in a small way only, for local consumption, and does not emerge into the larger trade channels. In the northern mountainous districts (fig. 12), the following valleys, among others, produce oat hay: Pitt River, Scott, Shasta, Battle Creek, Cow Creek, Clover Creek, Oak Run, and Milford. Throughout the northwestern coast counties oat hay prevails above all others, and is commonly met with in the following valleys: The northern half of the western part of Elk Valley, the Smith River Valley, and the Fort Dick sections in Del Norte County; the Arcata, Eureka, Ferndale, and Petrolia districts in Humboldt County; the Potter, Ukiah, Round, Willits, and Anderson valleys in Mendocino County; Big Valley in Lake County; and in practically all arable districts of the other coast counties to the south, including Sonoma, Napa, Marin, San Mateo, Santa Cruz, Monterey, and San Luis Obispo.

Oat Seed Production.—The principal market for thrashed oats in California is for hay seeding purposes, and is supplied partly by home production, and partly by importation of red oats, chiefly from Texas. Usually only a small part of the seed crop, not exceeding 1000 tons, is of sufficiently high quality to meet the exacting demands of the milling trade. The remainder is used as stock feed. The principal oat seed district is situated in the rolling hill lands tributary to the Bay of Monterey in central California (fig. 5). Formerly this territory produced oat seed on 15,000 to 20,000 acres, chiefly of the Coastblack variety, but in 1924 the area had fallen to about 3600 acres, principally Coastblack, distributed as follows: Springfield,

1500 acres; San Andreas, 1000 acres; Castroville, 600 acres; and Del Monte Junction, 500 acres. Coastblack oats are also produced in smaller quantities farther north, at Pescadero, Half-Moon Bay, Tomales, Fallon, Bloomfield, Cotati, Ignacia, Reclamation, Shellville, and Point Arena. California Red oats are also produced in the above

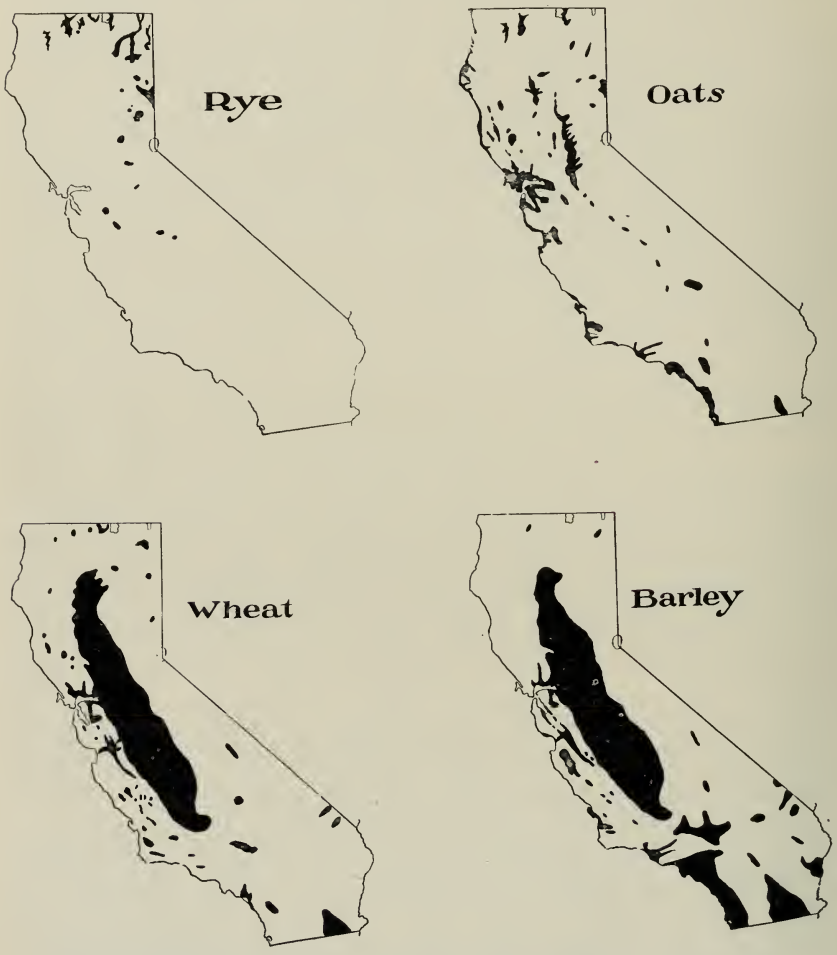

Fig. 4.—Range of cultivation for cereal hays in 1924. (p. 10 to 15.)

districts but extend into some of the interior districts as well—notably, the Stockton delta, the Sutter Basin, and eastern Stanislaus County. The last district is known for the high quality of its California Red oats, which frequently satisfy the exacting demands of the milling trade.

The Coastblack oat (fig. 10), both as a hay and grain crop, is produced exclusively in the coast regions of California, and is distinct from the black varieties of Oregon and Washington (p. 33). Because of its thick, coarse hulls and prominent awns, it generally weighs from five to seven pounds per sack less than the California Red oat, but customarily commands a premium of about ten cents per hundred above it. It is not used for milling and is confined exclusively to the coast regions of the state for hay and seed production.

Rye Hay.—Rye (fig. 13) offers great facilities for the production of an annual hay crop under two circumstances unfavorable to the growth of other cereals—namely, on poor, thin, sandy soils, and under climatic conditions of extreme severity. In consequence, it has taken precedence over the other cereals as a hay crop in the northern mountainous regions, and has, to that extent, widened the range of grain hay production in California (fig. 4). It has also an aptitude for withstanding the effects of drought, a circumstance which has added greatly to its value on the sandy soils of the San Joaquin Valley, where in many instances, as at Delhi, for example, it succeeds better than any of the other cereals. In Modoc, Lassen, and Siskiyou counties, rye hay is widely employed for fall planting on the dry ranches. Here it leads all other cereals in hay acreage, particularly in the lava bed section of the upper Pitt River, in the Butte and Red Rock valleys, and the Madeline Plains, and in the Milford, and Bieber sections. Scattered plantings are also made throughout the mountain valleys at high elevations in all of the eastern mountainous counties. In the San Joaquin Valley, the largest acreages occur on the sandy soils of the counties of San Joaquin, Stanislaus, and Merced.

GROUP CHARACTERISTICS

Considering the importance of the cereal hay crop on the Pacific Coast, surprisingly little attention has been bestowed upon it by the experiment stations. Some study of the four groups—barley, wheat, oats, and rye—has been made from the nutrition standpoint, but as to their comparative hay productiveness under different circumstances, there is but meager experimental evidence; and all of the questions centering about the relative merits of the numerous varieties of these four cereals for hay have been almost wholly neglected. On the other hand, much practical knowledge of the subject has been gleaned through years of practical experience, yet the evident disagreement among stockmen upon such questions as the most favorable stage for cutting affords the best evidence that a systematic study of

the entire field is needed. Many of the findings here reported are confirmatory of generally accepted opinions and practices, but in several instances they are decidedly contrary to them.

Comparative Hay Yields.—Each of the four cereals possesses well defined group characteristics which distinguish it from the others, irrespective of the varieties of which it is composed. Barley, for example, under favorable conditions in the Great Valley yields less hay per acre than the other three cereals,* yet in drought years it becomes the most productive of the four. As would be expected, the different varieties of each group react differently to climatic variations, and some are more injuriously affected by drought than others, but the general relationship stated above holds for the groups as a whole, and is concretely illustrated by the following records, taken from field experiments at the University Farm, Davis:

TABLE 2

COMPARATIVE *Hay Yields* OF BARLEY, WHEAT, OATS, AND RYE, UNDER FAVORABLE AND UNFAVORABLE CIRCUMSTANCES

Variety	Favorable year 1919 Yield in tons* per acre	Drought year 1920 Yield in tons† per acre	Per cent reduction due to drought
Coast barley	4.5	4.8	−6.6
White Australian wheat	7.0	4.2	40.0
Coastblack oat	6.6	3.7	43.9
Rye‡	6.8	3.8	44.1

* Average of 2, 1-16 acre plots.

† Average of 2, 1-2 acre plots.

‡ The rye used in these experiments is representative of the cultivated rye of northern California, and consists of a mixture of several types.

All of the hay variety trials for 1919 reported in tables 2, 4, 5, 6, 7, 8, 9, 10, 11, 12, and 13 were conducted upon a uniform rich loam soil, 20 to 36 inches in depth, underlain by a fine sandy loam of great depth. The preparation consisted of deep winter plowing, followed by a well-prepared summer fallow. Adjacent areas under similar treatment yielded 80 bushels of Coast barley and 60 bushels of White Australian wheat per acre. All seed was drilled: wheat, rye and barley at 80 pounds per acre, and oats at 60 pounds per acre, excepting the wild oat, which was planted at the rate of 100 pounds per acre. The crop was cut and cured in accordance with the current practices described on pp. 52 to 53. The hay yields obtained under these conditions were considerably higher than those resulting from usual field practice.

* As early as 1891, Hansen, in California Experiment Station Report 1891–92, pp. 186–189, reported average hay yields for six varieties of oats, eighteen varieties of wheat, and eight varieties of barley, grown at the Sierra Foothills Substation in Amador County, all planted December 11th, and with a seasonal rainfall of 29 inches, to have been 3861, 3763, and 2493 pounds of hay per acre, respectively. The Foothills Substation was situated five miles from Jackson, at an elevation of 1975 feet above sea level.

This simple test confirms the opinion generally entertained that barley is the most productive hay crop of the four cereals in the drier, more uncertain districts, and in seasons of extreme drought, but that under more favorable circumstances is the least productive. In the 1918–1919 season the four crops of table 2 were planted December 6th, on a well-prepared fallow, and received 19.4 inches of rain during their growth, but the 1919–1920 season they were planted January 8th, on a similarly prepared fallow, and received only 8.94 inches of rain. The first season was a favorable one for cereal growth, while the latter one was unfavorable. Barley suffered no decrease in hay yield, while the other three cereals were depressed in yield from 40 to 44 per cent. It has previously been conclusively demonstrated that barley and rye, with respect to *grain yield*, are more drought-resistant than wheat or oats, but in point of *hay yield* this solitary test would indicate that barley is even less affected by drought especially as compared to rye. For example, in the two seasons under discussion the *grain yields* of the four cereals were as follows:

TABLE 3

COMPARATIVE GRAIN YIELDS OF BARLEY, WHEAT, OATS, AND RYE, UNDER FAVORABLE AND UNFAVORABLE CIRCUMSTANCES*

Variety	Favorable year 1919 Yield in bushels per acre	Drought year 1920 Yield in bushels per acre	Per cent reduction due to drought
Coast barley	27.4	16.4	40.1
White Australian wheat	28.7	3.7	87.1
California Red oat	27.3	4.8	82.4
Rye	14.0	6.6	52.8

* Unpublished data from continuously cropped plots in rotation experiment, Davis, Calif., Project No. 174. - 1919–1920.

These figures unite with previous tests in demonstrating that the grain yields of barley and rye are reduced less by drought than those of wheat or oats, but in addition to this they show that the hay yields of all except rye are much less reduced by drought than grain yields under similar circumstances. In this instance the grain yields of wheat and oats suffered approximately double the percentage reduction of their hay yields, and barley, while suffering no reduction in hay yields lost 40 per cent in grain yield, and rye lost 8.7 per cent more in grain than in hay yield. Comparative hay yields for indivdual varieties of barley, wheat, oats, and rye are reported under *Varieties* (tables 6, 7, and 8).

Comparative Ripening Periods.—The ripening period of the crop is closely related to the yield of hay. During the seasons of 1919 and 1920 these periods were recorded as follows:

TABLE 4

Ripening Periods for Cereal Hays

Variety	Number of days to ripen* 1919	Number of days to ripen* 1920	Reduction in days due to drought and late planting	Per cent reduction
Coast barley	174	131	43	24.7
White Australian wheat	194	141	53	27.3
Coastblack oat	211	148	63	29.8
Rye	187	138	49	26.2

* Soft dough.

Fig. 5.—Red oat hay on old marine terraces overlooking the Bay of Monterey, in Santa Cruz County. The more accessible land at the right has been planted to potatoes. This is representative of the Coastblack oat hay district of the central coast region.

The significant relationship here brought out is that the order of ripening has been maintained in spite of the shortening of the growth period through a combination of drought and late planting in 1920. The planting dates were November 6 for 1919, and January 8 for 1920, or 64 days later. It is also noteworthy that the later maturing cereals—oats and wheat—not only sustained greater curtailment of growing period, but they also suffered more loss in grain yield than barley or rye, presumably partly in consequence of a more restricted growing season.

Height Growth in Relation to Yield.—It is somtimes assumed that height growth is a reliable index of hay yield and may be used in estimating probable tonnage per acre, but it is evident from measurements and correlations determined in 1919 and 1920 that no broad generalization can be made in this respect, and that each cereal apparently responds differently. Coast barley, for example, made exactly the same height growth, 46 inches, each season, and was not reduced in hay yield as a result of the drought. Rye, on the other hand, attained a height of 66 inches each season, but sustained a reduction in hay yield of 44 per cent. Wheat, however, was reduced from 68 to 42 inches in height, or 38.2 per cent, and yielded 40 per cent less hay, while oats fell from 60 inches to 54 inches in height, a reduction of only 10 per cent, yet lost 43.9 per cent in hay yield. From these observations it is clear that hay yield cannot be taken as a function of height growth uniformly for the four cereals, and while the data are not complete enough to admit of definite conclusions, they indicate that while height may give a general indication of hay yield in barley and wheat, it is less reliable in the case of oats and rye. It is also obvious that height growth alone is misleading as a standard of comparison in estimating the comparative hay yield of any two cereals, particularly under the influence of drought. For example, in 1920, a rye crop which measured 66 inches in height yielded only 3.8 tons per acre, while barley which measured only 46 inches in height yielded 4.8 tons per acre, and wheat which measured only 42 inches in height yielded 4.2 tons per acre.

Physical Composition.—Quality in cereal hays is customarily estimated upon the basis of texture, color, aroma, cleanliness, and amount of grain present. Oat and wheat hays generally possess more desirable characteristics as to quality than barley or rye, and are held at a premium on the market, but no previous attempt has been made to distinguish between the several varieties of wheat, oats, and barley, as to quality. The simple physical analyses following, in table 5, in which the hays cut in "soft dough" are separated into their component parts and the proportion of each by weight calculated, afford a means of comparing them physically, especially with respect to texture.

From these analyses it is evident that wheat and rye varieties rank above oat and barley varieties in proportionate weight of culm or stalk, but that there are no striking variations between varieties of the same cereal. Rye is highest, with 54 per cent; the wheat varieties average 48 per cent; the oat varieties 43.75 per cent; and the barley varieties 42 per cent. Coast barley, with 39 per cent stem, is lowest of the cereals in stem weight.

TABLE 5

PHYSICAL ANALYSIS OF CEREAL VARIETIES

Variety	Per cent culm (stem) by weight*		Per cent leaves by weight†		Per cent heads by weight‡	
Coast barley	39		25		36	
Chevalier barley (Two-rowed)	44	Av. 42	34	Av. 30	22	Av. 28
Nepal (Bald) barley	43		31		26	
White Australian wheat	47		33		20	
Little Club wheat	49		29		22	
Sonora wheat	50	Av. 48	27	Av. 28.8	23	Av. 23.2
Early Baart wheat	45		30		25	
Velvet Don (Durum) wheat	49		25		26	
California Red oat	42		26		32	
Coastblack oat	45	Av. 43.75	33	Av. 31	22	Av. 25.25
Roberts (side) oat	48		31		21	
Wild (A. barbata) oat	40		34		26	
Rye	54	Av. 54	25	Av. 25	21	Av. 21

* Stems cut four inches above crown and one inch below head.
† Leaf, including sheath.
‡ Head, including grain.

In proportionate weight of leaves, the oat varieties lead with 31 per cent; barley is second, with 30 per cent; wheat third with 28.8 per cent; and rye last with 25 per cent. Wild oats and Chevalier barley excel in leaf weight, with 34 per cent, while rye, Coast (common) barley, and Velvet Don Durum wheat were found to have the least leaves by weight, or 25 per cent. White Australian (Pacific Bluestem) wheat, which is considered one of the best hay wheats, had the highest percentage of leaf weight, while Sonora and Velvet Don had the lowest, or 27 and 25 per cent, respectively. Chevalier (two-rowed) barley, which is the best hay barley, had 34 per cent of its weight in leaves, while Coast (common) barley had only 25 per cent. Nepal (fig. 8) a beardless, hulless variety, was intermediate, with 31 per cent. The common wild oat (*Avena barbata*) proved to be the leafiest of the oats, with 34 per cent leaf, the Coastblack oat second, with 33 per cent, and the California Red oat lowest in leaf weight, with 26 per cent.

In head weight, the barley varieties ranked highest with 28 per cent, rye lowest with 21 per cent, and wheat and oats intermediate, with 23.2 and 25.25 per cent, respectively. Coast (common) barley lead all the varieties in grain percentage, with 36 per cent, while Chevalier barley, with its abundant fine leaves and stems, was one of the lowest, with 22 per cent. Among the oat varieties the California

Red, which is one of the best grain producers in this locality (Davis), exceeded all other varieties by disposing of 32 per cent of its weight in grain while in the soft dough. This circumstance accounts for its comparatively low percentage of leaves as compared with the other varieties. Coastblack and Roberts oats, which are late maturing varieties, and poorly adapted to the Sacramento Valley for grain production, yielded only 22 and 21 per cent of heads, respectively, by weight. The wild oat produced grain freely, but because of its deciduous seed habit was found to consist of but 26 per cent heads by weight in the soft dough. Rye, which ranked highest in culm

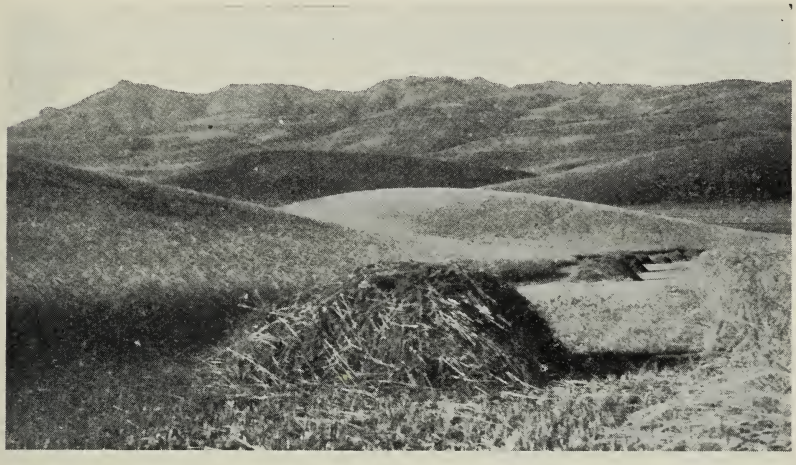

Fig. 6.—Barley in the Tres Pinos district of San Benito County. The 18-foot harvest lane has been cut to admit the combined harvester on its first "round." By this practice some 20,000 acres of standing grain are annually converted into hay in California.

(stem) and lowest in leaf, was also lowest in head weight, with 21 per cent. Rye normally possesses a long, tough, relatively leafless stalk, terminating in a slender, light head; but in addition to this it shatters its grain freely during the curing process, even though cut as early as the soft dough, all of which accounts for its low percentage head weight.

In general, oats, which because of their soft texture, are regarded as the most palatable of cereal hays, were found to contain the highest percentage of leaves and a moderate amount of grain and stalk. Wheat, which also yields a high quality hay, consisted of a relatively high percentage of leaves, especially in the more desirable varieties, such as White Australian (Pacific Bluestem), a rather high percentage of stem, and a low percentage of heads. The barley varieties

showed considerable variation in physical composition, and the Coast (common) variety, which is inferior for hay making, ranked high in grain, with a corresponding reduction in leaf and stem, while Chevalier, which yields a very superior grade of hay, ranked low in head weight and high in fine textured leaves and stems.

VARIETIES

In the main, the cereal varieties used for hay are among those used for grain in the district. Exceptions, such as the use of Coastblack oats in the northern coast districts, are due to special climatic requirements or to special quality, such as the use of Chevalier or Nepal (Bald) barley in some of the interior districts. In the case of wheat, a preference is usually given to the beardless varieties for hay because of their supposed greater palatability. What is designated palatability, however, is usually determined by a combination of causes, and is closely associated with such factors as stage of maturity when cut, or the methods employed in curing. It is equally certain, too, that there is a very wide variation between the palatability and nutritive effect of such widely divergent kinds of hay as, let us say, rye and oat, even though they may have been grown and cured under identical conditions, and similar differences although less apparent, as will be pointed out later, exist between the different varieties of each group of cereals.

Prolificacy is also a varietal characteristic, and individual wheat varieties may vary as much as a ton or more of cured hay per acre in productiveness (table 7), according to their adaptation to the locality. Barley varieties are also variable in this respect, and differences as great as 1.7 tons per acre have been recorded between the Coast type and the short growing California Mariout (p. 23). Oat varieties, too, show specific adaptation to localities, the slower growing, semi-winter Coastblack decisively outyielding the California Red oat in the cooler coast districts when "fall-planted," but the California Red oat generally outyielding the Coastblack when "spring-planted" in the same district.

Barley Varieties

Well over 90 per cent of all of the barley hay made in California is of the "Coast," or "Common," type, but owing to the influence of the Experiment Station in recent years a large part of this is now composed of such improved varieties of the common type as Tennessee Winter, Four Thousand, and Beldi, which surpass the "Coast"

in grain yield, but are so similar to it in appearance that their identity is generally lost sight of, and they become known as common barley. For hay making, however, these varieties are so nearly identical that no significant distinctions can be drawn between them.

Mariout Varieties, on the other hand, which have attained some prominence in California during the last decade, possess more distinctive characteristics. California Mariout was distributed from Davis to meet the demand for an early-maturing, drought-resistant barley, adapted to dry soils and climates, and under these conditions it has proved to be a more productive grain crop than the varieties of the Coast type, but as a hay producer it is, on account of its dwarf habit of growth, the least productive of the important commercial varieties. This was demonstrated in a test at Kearney Park, Fresno County, in 1921, when the following observations were made by Gilmore:[3]

Variety	Grain per acre	Hay per acre
California Mariout barley	4152 lbs.	5142 lbs.
Coast (common) barley	3765 lbs.	8548 lbs.

In this instance, which is representative of the performance of the two varieties under average San Joaquin Valley conditions, California Mariout produced 10.2 per cent more grain than Coast barley, but Coast produced 66.9 per cent more hay than Mariout.

Club or Oregon Mariout barley entered California in commercial quantities through Oregon in 1918, and has since attained considerable prominence in the Sacramento Valley, particularly in Glenn County and vicinity. It has little in common with California Mariout, either in appearance or adaptation, and owes its popularity chiefly to an attractive appearance and consequent demand for export shipment for malting purposes.

Recent controversies among English and Scotch malsters as to the value of this barley have reacted unfavorably upon its market value in California and resulted in reduced acreages in 1924–25. The kernels are large, plump, light colored, and enclosed in a thin hull. The straw is of about the same height and texture as that of Coast barley, and the head is compact and club-like. It ripens at the same time, and is in general adapted to the same conditions as common Coast barley. It does not possess the specific drought tolerance of California Mariout. In grain yield it is slightly superior to Coast, and in hay yield it seems only slightly less productive.

[3] Report Calif. Agr. Exp. Sta., 1920–21, p. 32.

Chevalier barley is the name used in California to designate all barley varieties of the two-rowed (*Hordeum distichum*) type, and includes several varieties similar in appearance, use, and adaptations. In acreage, Chevalier barley is of only minor importance, and generally not more than 10,000 acres are grown for both grain and hay, or less than 1 per cent of the usual total barley acreage of the state. It is more exacting in its soil and climatic requirements than the common type, and is restricted to the stronger soils in the cooler districts of the state. As a grain crop it compares favorably with Coast in the districts to which it is adapted, but in the semi-arid

Fig. 7.—A typical coast dairy in Humboldt County of northern California. There is little irrigation or alfalfa in the northern coast regions, but abundant rainfall and continuously cool weather. The feeding requirements are met with oat and vetch hay, supplemented by roots and green pasturage. The cool climate is favorable for roots, and with high rainfall the pastures remain green longer than in the interior. The roots, which are visible in the enclosure above the barn, are fed for "succulence" during the fall and winter in lieu of green pasturage or silage. The hay and grazing land surrounds the barn and the homestead in the distance. (p. 35).

interior of the state, on dry-farmed land, it yields only about 75 per cent as much grain as Coast. As a hay crop, on the other hand, it excels Coast in yield (table 6) in all situations and is much superior in quality, and for these reasons should command a wider attention among farmers as a hay crop in the barley growing areas.

The grain, which is plump and thin-hulled, is peculiarly suitable for the manufacture of pearl barley, and a large part of the grain crop, which seldom exceeds 200,000 sacks, is sold at a considerable premium over common barley for this purpose. A smaller portion

is also consumed in the manufacture of malt. Chevalier straw, remaining after thrashing is more highly esteemed as a stock feed than that of other barley varieties, and is largely baled and utilized by stock feeding establishments.

About 98 per cent of the Chevalier grain produced in California originates within a narrowly circumscribed area, situated upon the fertile alluvial soils of the lower Salinas Valley, partly irrigated, and extending inland not more than twenty-five miles from the sea. Other small plantings are generally to be found about Alvarado, Livermore, Santa Maria, and San Juan.

As a hay crop, Chevalier barley has not received the attention from Californian farmers which it deserves. It is almost unknown on the hay markets of the state, and only a few discriminating feeders here and there cling to it, and continue to produce it in small quantities as a hay crop for home consumption. In quality, Chevalier barley hay more nearly resembles wheat or oat hay than it does that of other types of barley. The stalks are softer, finer, and leafier (table 5), the beards finer, and it is fed with less waste—in fact, it compares very favorably with the best wheat hay in all of its feeding properties. In addition to this it possesses greater drought resistance than wheat or oats, and is commended to the attention of feeders in dry, hot districts where wheat and oats do not thrive, and where Coast barley is now planted exclusively for hay production.

Bald barley, frequently known as beardless or hull-less barley, and generally composed of the variety Nepal, has had a long agricultural history in California, but has never emerged from its position of comparative obscurity (fig. 8). It was first introduced into the state and recommended for trial as a hay crop by the Experiment Station in 1884,[4] and numerous writers have called attention to its merits since that time. It has frequently excited interest through the peculiarity of its grain thrashing clean of the chaff, like wheat, and those unfamiliar with it might easily mistake a thrashed sample of it for wheat. But the special characteristic upon which its reputation as a hay crop is chiefly based is the beardless character of its heads, which lessens the possibility of the sore mouths frequently occasioned by the feeding of well matured barley hays of the barbed awn type.

Because of its beardless character, Nepal has won many adherents among the stockmen of the state, and its distribution as a hay variety has become more general than that of Chevalier, although it has never been recognized by the wholesale hay trade. Like the

[4] Dwinelle, C. H., Calif. Agr. Exp. Sta. Bull. No. 22, Nov. 15, 1884.

other barleys, it is drought-resistant and succeeds well in the interior districts of the state, and small plantings of it may be found in many counties. It possesses specific adaptation to our mountain valleys, no doubt an inheritance from its native habitat in the elevated mountain valleys of the Himalayas, and scattered small plantings are regularly made throughout the foothill and mountain valleys upon the western slope of the Sierra Nevada Range, where it is regarded as a satisfactory hay for work horses.

Fig. 8.—Bald barley, otherwise known as beardless, hulless, or Nepal barley, has many adherents among stockmen as a hay crop, because of the beardless heads; but aside from this it has little to recommend it. It yields a hay coarser in quality and lower in productiveness or nutritive value than either Coast or Chevalier barley. (p. 25.)

The chief demerit of Bald barley, and oddly enough this has been generally overlooked, lies in the coarseness and harshness of its leaves and stems, characteristics which alone are sufficient to disqualify it for general use in localities where other varieties can be grown. Some feeders, too, have complained that the hardness of the kernels becomes objectionable for feeding when the hay is cut near maturity.

In feeding tests at Davis it was found that young dairy stock when fed on barley hay exclusively not only ate Chevalier and Coast barley hay with less waste, but made better gains in body weight than when fed Nepal barley hay (table 15).

In the field, Nepal barley grows to about the same height as Coast (common) barley, but because of its erect, stiff stems which do

not "droop over" or lodge, it generally appears even taller at harvest time. Under comparable conditions in 1919, Coast was 46 inches in height at maturity, and Nepal 48 inches. In the field Nepal barley gives the impression of early maturity because of its erect, beardless heads, which "turn color" earlier than those of the other barleys, but the actual time elapsing from planting to soft dough, as judged by the condition of the grain itself, proved to be virtually the same, or 174 days for Coast, and 177 days for both Chevalier and Nepal. This is a much shorter period than that recorded for any of the wheat, oat, or rye varieties grown under the same conditions (table 10).

Barley Variety Trials.—Coast, Chevalier, and Nepal barley varieties were chosen as representatives of the six-rowed, two-rowed, and hooded hulless types, respectively. They were grown in 1919 in duplicated $\frac{1}{16}$ acre plots, to determine their relative productiveness as hay crops, and their hay yielding capacity as a group compared with that of wheat, oats, and rye. The seed was drilled at the rate of 80 pounds per acre on well prepared summer fallow on November 6, and perfect stands were secured in all cases. The average yields of air-dry hay in tons per acre were recorded as follows:

TABLE 6

Hay Yields of Barley Varieties

Nepal	4.33 tons per acre
Coast	4.51 tons per acre
Chevalier	4.65 tons per acre

The average yield of these three barley varieties was about 34 per cent less than the average yield of five wheat varieties grown under comparable conditions, but there is not sufficient difference in yield between the three varieties to warrant an opinion as to their probable relative productiveness under other conditions. Chevalier yielded slightly more than the others, as might be expected from its heavier stooling habit. It was also found to be composed of a higher percentage of leaves by weight than the others—34 per cent by weight of the entire plant as cut by the mower consisted of leaves, while the leaves of Coast and Nepal comprised only 25 and 31 per cent, respectively (table 5). This greater leafage of Chevalier is probably a contributing factor in the greater nutritive value of its hay (table 15).

Wheat Varieties

White Australian (Pacific Bluestem) wheat (fig. 9) possesses all of the requisites of a hay variety, and is universally liked in all of the northern districts for its wide adaptation, superior quality, and general utility. It is extensively employed for grain production, and is also the variety most often planted for hay in the exporting centers of Alameda, Contra Costa, and San Benito counties. In the northern mountain valleys it has a general distribution under the name Bluestem, and is there a favorite for spring planting. It is little known either as a grain or hay crop in southern California, where it is generally replaced either by the more drought-resistant Sonora in the interior districts, or by the more rust-resistant Defiance in the coast districts. As a hay variety it possesses prolificacy and quality, each in a very unusual degree, and is, by common opinion, one of the best of the hay wheats. It matures late and requires more moisture than some of the other varieties, but under favorable conditions produces a tall, leafy growth with beardless heads, and is the highest hay yielder of the commercial wheats tested at Davis. A physical analysis of the hay (table 5) showed it to possess the highest percentage of leaf, by weight, of any of the wheats examined. At maturity it stands about 6 inches taller than Little Club (fig. 9). The stalks are coarser than those of Baart or Sonora, but the hay is eaten as readily, and it produced the second highest gain in body weight per pound of the twelve cereals, when fed as an exclusive ration to dairy heifers (table 15), and surpassed all other cereals in total nutritive value per acre.

Little Club wheat (fig. 9) is not so often planted for hay as White Australian, but through its general popularity as a grain crop in the northern cereal districts of the state it has become well identified with the hay trade. Like White Australian, it is a late maturing variety, requires more moisture than some of the other earlier maturing sorts, and consequently is seldom grown in the San Joaquin Valley or in the south. It is, on the whole, regarded as a very satisfactory general purpose grain and hay variety, its non-shattering properties insuring its popularity as a grain crop, while its beardless heads have given it precedence as a hay crop over all bearded wheats in the estimation of many farmers. But in the strictly hay producing districts its more general utilization has been retarded by its yield and the quality of its hay in which it is surpassed by White Australian. In feeding tests at Davis, dairy heifers did not

do so well on it as upon White Australian (table 15), and it ranked with Durum wheat as the poorest of the wheat hays tested.

Sonora.—The popularity and extensive use of Sonora as a grain and hay variety is due to its aptitude for vigorous growth and prolific grain yield under conditions of extereme heat and aridity. This characteristic alone, in spite of its inferior milling quality and comparatively low hay yield, has given it precedence over other varieties for grain production in the southern San Joaquin Valley, and in the

Fig. 9.—Two leading California hay wheats ready for the mower. White Australian, at left, is universally admired for its hay making properties, and possesses prolificacy and quality, each in a very unusual degree. As compared with Little Club, at right, it is taller, leafier, more prolific, and possesses greater nutritive value. The yields of cured hay from the plots shown were: White Australian, 7.05 tons per acre, and Little Club 6.55 tons per acre. (pp. 28 and 29.)

interior districts of southern California. In the north it finds little favor either as a grain or hay crop in competition with more prolific varieties, except for spring planting on moist soils, for which purpose it possesses distinct advantages over the other varieties which are more sensitive to hot weather during the ripening period. As a hay crop it is short in stem, low in yield, scanty in leaf, and carries an unusually high percentage of its weight in the stalk (table 5). But the hay is soft in texture, and when fed as an exclusive ration to dairy heifers produced the highest gains in body weight of any of the cereal varieties (table 15).

Early Baart.—Since its introduction in 1900, this variety has become a popular milling wheat and has been widely planted for its productiveness, drought-resistance, and excellent market qualities. It possesses a wide range of adaptability, and is grown from the mountain valleys of the north, through all of the central portions of the state to the Imperial Valley on the Mexican border, where it is grown under irrigation. Its bearded head, which is its chief demerit as a hay variety, has made it unpopular with the hay buyers and dealers. For this reason it is never planted exclusively for market hay production. But through its wide distribution it inevitably appears on the hay market, sometimes pure, although more often in a mixture with other varieties. It is one of the tallest, earliest maturing wheats grown in the state, equalling White Australian in height and standing next to it in hay yield. The hay has a high percentage of leaves, and a low percentage of stems, by weight (table 5), but the latter have a wiry character which is undesirable. In feeding tests the stock did not do so well upon it as they did upon the Sonora or White Australian (table 15).

Bunyip is one of the newer varieties, introduced from Australia, and widely distributed in California since 1915. It is beardless, of medium height, and grows rapidly. It is well adapted to the Sacramento and San Joaquin valleys and has succeeded somewhat better than Club or White Australian for grain production upon the lighter soils and in the drier climate to the southward in the San Joaquin Valley. It has much of the appearance of White Australian, although little of the latter's quality. In its adaptation, earliness, and milling quality it more nearly resembles Early Baart. It has not been extensively planted solely for hay production, except in the Altamont region of Alameda County, where the hay has been accepted, without market discrimination, as White Australian. Comparative tests, however, show it to be shorter than White Australian, and its hay coarser and for these reasons it is not recommended where hay production is the end in view.

Defiance.—While variable in type, this variety resembles White Australian very closely in its field characteristics, but differs from it in possessing greater resistance to rust. This circumstance has established its reputation as a suitable variety for the mild, humid climates of the southern coast counties, on the hill lands near the sea where it is grown in preference to other wheat varieties. It is tall, late in maturing, and beardless, with good hay qualities, and should rank with White Australian in hay productiveness and nutritive qualities, though the hay is somewhat coarser and harsher.

Galgalos is a beardless, red chaff variety, seen only occasionally in California, and then chiefly as a spring variety in the northern mountain valleys. It has little to recommend it either as a grain or hay variety, and is objectionable as a hay crop because of its weak straw and pubescent leaves.

Propo.—This wheat offers some marked points of resemblance with Early Baart. Both are bearded, possess tall weak straw, and mature early. Propo, which may be generally distinguished by its purple tinted stalks, is slightly less prolific as a grain crop, and less in demand for milling. It is only occasionally used for either hay or grain, and is rarely grown except in a few localities in the central coast and southern regions of the state.

Hard Federation is one of the newer beardless Australian hybrids, distributed by the Experiment Station since 1920. It has met with a favorable reception as a grain crop in some of the more arid wheat districts, but its popularity there has been impeded by its shortcomings as a hay crop. As a grain crop it is early, fairly resistant to shattering, and high in yield and milling quality; but as a hay crop its yield is scanty and of inferior quality. These defects have prevented its wider acceptance in California, where general utility is demanded.

Wheat Variety Trials.—White Australian, Little Club, Sonora, Early Baart, and Velvet Don wheats were included in a comparative hay yield test. The first three represent varieties which are extensively used and highly esteemed for hay production; the fourth, Early Baart, is a variety usually discriminated against as a hay crop because of its bearded heads; and the last, Velvet Don, is a typical Durum or macaroni wheat, entirely distinct from the others in its physical and agronomic characteristics, and is representative of a large group of varieties unknown to Californian commerce. The cultural details are described on pages 16–27. The yields of air-dry hay were as follows:

TABLE 7

HAY YIELDS OF WHEAT VARIETY

White Australian	7.05 tons per acre
Little Club	6.55 tons per acre
Sonora	6.28 tons per acre
Early Baart	6.75 tons per acre
Velvet Don	7.60 tons per acre

Velvet Don outyielded the bread wheat varieties by a margin sufficient to leave no uncertainty regarding its greater productiveness

as a hay crop under the conditions of this test, and judging by the vigorous vegetative development of the Durums as a class, they will doubtless be found to exceed in hay yield the bread wheats as a class. But however promising their productivity, they are unfortunately endowed with several pronounced faults, any one of which would exclude them from serious consideration as desirable hay crops. In the first place, they possess conspicuously long, stiff, tough beards, even more objectionable in feeding than those of barley. Secondly, the stalks, while small in diameter, are tough and wiry. Thirdly, the leaves are the smallest of any cereal examined, and compose less of the total weight of the plant than do those of any except rye and Coast barley (table 5). Fourthly, as might be expected in view of these facts, stock fed with this hay made lower gains in body weight, with one exception, than with any of the twelve cereals tested. In addition to these defects the crop is very late in coming to maturity (table 10) and lodges badly when grown on rich land.

The lowest yield was made by Sonora, a finding fully consistent with current opinion, and correlated with its scanty leafage, which amounted to only 27 per cent of the crop by weight, in comparison with 33 per cent for White Australian and 30 per cent for Early Baart. This correlation, however, does not extend to some other types of wheat. Velvet Don, for example, had the lowest leaf percentage (table 5) and the highest yield. The difference in yield between the other hay wheats was very slight. White Australian exceeded Baart by about .3 tons per acre, and Baart exceeded Club by only .2 tons per acre. It was worth noting that Sonora, the least productive, ranked first in feeding value, while Velvet Don, the most productive, ranked lowest.

Wheat, as a class, was more productive than barley, and the five wheats were uniformly high in yield in comparison with the three barleys, which were uniformly low. It is also significant (table 5) that the greater part of the weight in wheat hay lies in the leaves and stalks, while in barley hay, especially in the six-rowed types such as Coast, a considerably higher percentage lies in the head and grain.

Oat Varieties

California Red, also known as the Texas Red, and Red Rust Proof, is the most extensively cultivated and widely adapted oat in California (fig. 10). It is comparatively tolerant of heat and aridity, and consequently finds greatest favor in the larger agricultural areas of the interior, though like the other oats, it prefers the coast climate,

and there produces the largest yields of grain and hay. But the extremely damp and cold climate of the northern coast, particularly in situations exposed to the continuous sweep of the moisture-laden trade winds, is uncongenial to it, and there is replaced by the hardier Coastblack variety. Seed of the California Red oat is produced in both the coast and interior districts, but that from the coast is generally superior, and may be distinguished by its greater size, weight, plumpness, and deeper red color. Seed grown in the interior may also be of excellent quality, especially when produced in favorable season and abundantly irrigated, or otherwise adequately provided with soil moisture.

As a hay crop, the California Red oat surpasses the other in quality, and is the leading hay oat in all of the principal agricultural areas excepting in the northern coast districts, but in hay yield at Davis it ranked lowest of the oats tested with the exception of the wild oat Its response to a hot, arid climate is early maturity, short straw, and a quick filling of the seed. This accounts for its comparatively greater seed prolificacy and inferior hay productiveness under such conditions. For example, on April 17, 1920, the California Red oat measured only 3 feet in height, while the Coastblack measured 3 feet, 6 inches (fig. 10). This was 40 days before the Red oat had reached the "dough" stage, and 49 days before the black oat had attained a similar degree of maturity. But when cut in the "dough" the California Red consisted of 32 per cent "head" by weight, while the Coastblack consisted of only 22 per cent "head" by weight (table 5). This deficiency in hay yield is amply made up by superior hay quality, for the stalks and leaves are the finest, softest, and most pliable of the cultivated oat varieties. But for the same reason, it is the most prone to lodge when grown on rich land. It is also among the first of the oats to ripen, and at Davis was ready for hay 10 days before the Coastblack (table 10). Oats as a class are later in maturing than the other cereals. The red oat, for example, required 202 days to reach the "soft" dough" stage, or 10 days more than Sonora wheat, 15 days more than rye, and 28 days more than Coast barley (table 10).

As a feed for horses, California Red oat hay takes precedence over that of all other cereals, but as is pointed out later, when fed to dairy heifers as an exclusive diet, it, together with the Coastblack, resulted in the lowest gains in body weight of any of the thirteen cereal hays included in the test (table 15).

Coastblack (fig. 10).—Botanical evidence indicates that the Coastblack oat, like the California Red oat, is of Mediterranean origin, but

how or when it was introduced into California is as yet not known. It is classified botanically as *Avena byzantiana,* which is the group of the California Red oat, but agronomically the two varieties are distinctly different, particularly in adaptation and utility. The Coast-black is lacking in quality, and is less in demand either as a hay or grain crop than the red oat. It is taller, later in maturing, and coarser, and is affected less prejudicially by the harsh coastal climate of northern California, where in fact it flourishes. Coupled with its

Fig. 10.—Contrasting the two leading California oat varieties, California Red at left, and Coastblack, at right: each possesses specific climatic adaptation and geographic distribution, and they differ greatly in both grain and hay productiveness under different environments. The red is finer in quality, but gave the lowest gains in body weight when fed as an exclusive ration to dairy heifers of any of the thirteen cereals examined. The cured hay yields in the plots shown were: black, 6.59 tons per acre, and red 6.43 tons per acre, but the black required 10 days longer to reach the "soft-dough." (pp. 33–34.)

hardiness and late maturity is its semi-winter habit and long dormant period, which in a measure inure it to "drowning out" when "dry-planted" in the fall in heavy, poorly-drained soils. By virtue of its late maturity it prolongs growth late in the season, and even with a scant moisture supply it generally succeeds in making more hay than the red oat. In the interior this is, of course, at the expense of grain production, but in the coast regions it continues to develop after the soil has become dry, probably greatly benefited by the humid atmosphere, and produces relatively large amounts of hay and grain.

Practically all of the black oat hay is grown by dairymen for winter feeding. The majority of the dairy farms are leased by tenants, and are poorly equipped for field work (fig. 7). Much of the land is of heavy texture, and is "dry plowed," broadcasted, and harrowed before the fall rains. Low places in the fields remain wet for long periods, which is one reason that the black oat with its winter dormancy often "turns out" better than the red. The coast dairymen, however, prefer the California Red oat for spring planting after March first, for the reason that the black variety planted at that season starts too slowly, remains semi-dormant well into the summer, and fails to yield as satisfactorily when cut in the fall. Conversely, when the two varieties are planted side by side in a coast district in the fall, the California Red "heads" and matures in the early summer, while the black continues to grow vegetatively all summer, and ends by yielding a much greater tonnage of hay in the autumn.

Another advantage, that of greater rust resistance, is generally credited to the Coastblack oat, and frequently advanced in explanation of its preëminence in the coast regions. Comparative tests by the Experiment Station support this opinion.

Wild Oats (fig. 11).—Two species of wild oats, *Avena barbata* and *Avena fatua,* are generally distributed in California and highly esteemed as pasture and wild hay plants. They are, according to all botanical evidence, introduced species from the Mediterranean region, but at what time or by what agency they came to the new world has not been accurately determined. Their very wide and general distribution, however, in the Pacific Coast area suggests a very early arrival. Some of the first explorers in California mention them, the Indians have names for them, plant remains of it have been found by the writer in the adobe walls of the San Juan Bautista Mission, erected between 1805 and 1813, and there is the remote possibility that archaeological studies in Mexico and Central America may yet reveal plant remains which will establish their prehistoric introduction into the Western Hemisphere.

Of the two species, *A. barbata* has the wider distribution and succeeds in the more difficult situations, while the other, *A. fatua,* is more frequently met with on the better soils in the more temperate climate of the coast region, but from an agronomic viewpoint the two varieties may be considered identical. Both are capable of producing seed and perpetuating themselves with meager supplies of moisture. Both produce some seed which does not germinate the first year, but remains dormant in the soil for one or more years and then often unexpectedly produces a vigorous crop. With such drought-resisting

and evading equipment wild oats have continued to occupy extensive areas of rough hill lands in California, too dry for even cereal hay production, and to persist there after many other species both annual and perennial, less able to cope with the exigencies of the situation, have been exterminated through heavy pasturing.

Wild oats in mixture with bur clover are commercially known as stock hays, and as such are in active demand at from $2 to $5 a ton less than tame oat hay. Wild oats also occur in grain fields in nearly all sections of the state, and frequently multiply until they become so abundant that summer fallow must be resorted to, solely to secure a moderately clean crop of wheat or barley. Cultivated oat hay always contains some volunteer wild oats and in the flats to the north of San Pablo Bay the presence and persistence of wild oats is a decisive factor in devoting large areas to the production of hay rather than of grain. When wild oats occur abundantly in wheat hay, the product is quoted on the market as "wheat and oat hay," but contrary to popular opinion, cultivated oats are never planted with wheat to produce the market product known as "mixed wheat and oat hay." Neither are wild oats ever planted alone as a field crop in California. There is no seed to be had, and very little is generally known of their relative productiveness and response to cultivation.

In order to study wild oats under cultivation, the writer succeeded in separating several bushels of pure seed (principally *A. barbata*) from barley grown at Davis, utilizing as the principle of separation the dense hairy covering of the seeds, which served to impale them in the meshes of a round-holed screen, but allowed the barley kernel of the same and smaller diameter to pass through. Owing to their hairiness, and to the geniculate character of the awns, the seed is very light, fluffy, and difficult to manage when placed in a grain drill, collecting in woolly balls, which do not feed through the mechanism uniformly. But with considerable patience and some auxiliary hand planting, seeding was successfully accomplished on two $\frac{1}{16}$-acre plots (fig. 11) in a series with twelve other cereals and a fair degree of uniformity in stand obtained. The wild oat was in no perceptible degree earlier in maturity than the California Red oat, but paralleled it uniformly throughout its development by blossoming and reaching the "milk" and "dough" stages simultaneously with it. Both varieties were in the soft dough May 27, or somewhat earlier than the other oat varieties, but later than the barleys or wheats, excepting Velvet Don (table 10). But the wild oat is peculiar in that the kernels ripen progressively from the top spikelets of the panicle downwards, and are easily whipped out and

fall to the ground as they ripen, so that after a strong wind the empty panicles alone are held aloft. This peculiarity accounts for the difficulty of eradicating it on continuously cropped grain land, and imposes an insurmountable obstacle to its culture as a field crop, as there would be difficulty in obtaining seed in any quantity unless they were collected by hand picking as they matured. It stood about four inches shorter than the red oat and yielded at the rate of 5.06 tons to the acre, or 1.37 tons less. This relative unproductive-

Fig. 11.—The wild oat (*A. barbata*) under domestication. This is one of the most useful, and at the same time one of the most objectionable wild plants in California. Through its drought-resisting and evading properties, it has greatly augmented the carrying capacity of range lands, but through the same properties it has assumed the role of our most annoying grain field pest. It offers little inducement for cultivation, for although it ripens at the same time as the red oat, it lodges easily and is less prolific. Moreover, the seed falls to the ground as it ripens and, because of its hairy coating and twisted awns, is not amenable to machine planting. Part of the seed remains dormant in the soil one or more years, which, coupled with its deciduous seed habit, makes it difficult to eradicate once it has become entrenched in the soil. (p. 35.) Note the abundant fine stems and foliage.

ness of the wild oat was here perceived more clearly than had been expected from previous casual comparisons between luxuriant stands of wild oats and neighboring fields of less thrifty cultivated oats. The quality of the hay was excellent. It possessed the finest stems, and the stems composed the lowest percentage of the total weight of the plant of any of the cereals examined excepting Coast barley. The leaf percentage was relatively high (table 5), and it was found to be more palatable and nutritious than California Red oat or Coast-black oat hay when fed as an exclusive diet to dairy heifers (table 15).

It lodged more than the California Red oat, and of course could not be harvested for seed; in fact, it intrenched itself so well on these two plots through its deciduous seed habit and partial seed dormancy that several years were required to eradicate it.

Roberts.—A few varieties of white oats are grown in a small way in northern California, where climatic conditions are similar to those of the white oat districts of the eastern United States, but varieties of this class require a long, cool growing season, with abundant moisture, and do not succeed well in the Great Valley.

Fig. 12.—The wide range of soils upon which oats thrive, coupled with their low temperature requirements, has made them the most popular of cereal crops in the mountain valleys of northern and eastern California. Scene in Trinity County.

An exteme type of late maturing white oats—the Roberts—was included in the test for the purpose of comparison, and while it yielded a large tonnage of hay (table 8), it proved too coarse and too harsh in texture, particularly as a hay for horses. On a rich, well fallowed soil at Davis, in a favorable season, it attained a height of 64 inches, and lodged badly, yet it was eaten readily by dairy cattle, which throve fairly upon it even as an exclusive diet. It proved to be the latest maturing cereal grown (table 10), but previous tests have repeatedly demonstrated its unsuitability for seed production in any other than the northern mountain and coast districts of the state.

Burt.—This is a promising gray-seeded variety, which has been distributed by the Experiment Station, and recommended for seed

production in the drier interior districts. It possesses early maturity, stiff straw, and a more rapid, erect winter growth than the California Red oat. It has met with some favor and the acreage has been gradually extended.

Guyra and *Fulghum* are two of the newer oats which have given promising grain yields at Davis in recent years. Their hay qualities have not yet been studied.

Oat Variety Trials.—Four varieties of oats, California Red, Coast-black, Roberts, and wild (*A. barbata*), were grown on plots in the manner described on pages 16 and 27, and yields of air-dry hay recorded as follows:

TABLE 8

Hay Yields of Oat Varieties

Roberts	6.81 tons per acre
Coastblack	6.59 tons per acre
California Red	6.43 tons per acre
Wild oat	5.06 tons per acre

As a class oats have proved more productive as hay crops than barley, and compare favorably with wheat in yield. The four varieties averaged 6.22 tons per acre, as compared with 4.49 and 6.84 tons, respectively, for barley and wheat. There was comparatively little difference in the productiveness of the three cultivated varieties. The wild oat proved to be about 23 per cent less productive under the conditions of the experiment, but it should be remembered that the stand, owing to planting difficulties, was less uniform than that of the other varieties with which it is here compared.

Rye

Rye (fig. 13) commends itself to the attention of Californian farmers chiefly because of its aptitude for vigorous growth in poor soils and cold climates in the northern mountainous regions. Rye hay, because of its dry and ligneous character, is less palatable to livestock than hay of the other cereals, and for this reason it is not entitled to consideration except in places where the other cereals cannot be successfully grown. Such conditions occur chiefly in Modoc, Lassen, and Siskiyou counties. Here rye may be planted in the fall, survive the freezing of the soil during the winter, resume vigorous growth in the spring, and yield a satisfactory hay crop without irrigation, and with a minimum of spring and summer

rainfall. Rye is the most certain and prolific cereal for this purpose. The ordinary California cereal varieties winter-kill when fall planted under such severe climatic conditions, and are less prolific than rye if planting be delayed until spring. Dry mountain ranches, without wild hay or irrigation for alfalfa, use rye as a hay crop, and occasionally a dairy herd is maintained throughout the winter months on carefully made rye hay.

Fig. 13.—Rye commends itself to the attention of California farmers as a hay crop, chiefly because of its adaptability to poor soils and severe climates in mountainous regions. The quality of the hay is inferior to that of the other cereals, and for this reason it is not entitled to serious consideration as a hay crop, excepting in situations where the other cereals may not be successfully grown. Rye generally exceeds the other cereals in height growth, but from the standpoint of tonnage its appearance is deceiving, and it generally stands between oats and wheat in yield. If cut in the "blossom" to produce hay comparable to that of the other cereals in quality, it becomes the least productive of the cereals.

The commercial rye of California consists of several types badly mixed through hybridization, although some Rosen rye, a hardy winter variety introduced from Russia by the Michigan Agricultural Experiment Station, in 1909, is now being used for fall planting in the northern districts.

In comparative tests at Davis, rye yielded at the rate of 6.83 tons per acre, or slightly more than the highest yielding barley variety, approximately the same as the highest yielding oat variety, but slightly less than the highest yielding wheat varieties (table 7). Rye generally exceeds the others in height (fig. 13), but the appearance

of the crop before harvest is deceiving in estimating the tonnnage. Rye and barley both reached the blossom stage in 161 days from planting, considerably earlier than wheat or oats (table 11), but barley passed into the soft dough 12 days thereafter, while rye required 25 days (table 11). But as rye should be cut in the blossom, while barley should be cut later, rye becomes the earliest of the cereal hay crops. It should be remembered though that rye loses more in weight by early cutting than barley; that is, rye was found to gain 2.07 tons per acre in weight between the "blossom" and "dough" stages, while barley gained only .17 tons per acre (table 9). It is essential to good quality, however, that rye be cut in the blossom or earlier, and for this reason it should be regarded as falling in the barley class rather than the wheat and oat class in productiveness. A physical analysis of "dough" rye hay showed a relatively low percentage of leaves and head by weight, but the highest percentage of stalk of any cereal examined (table 5). Moreover, the stalks were exceedingly tough and wiry in "dough" rye hay, but much better in texture in "blossom" rye hay. Nevertheless the heifers fed an exclusive diet of "dough" rye hay made higher gains in body weight than when fed exclusively on oat hay, but not so great as when fed on wheat or barley hay.

CULTURE OF CEREAL HAYS

Soil Preparation.—Less labor is generally bestowed upon the preparation of land for cereal hay than for grain, and the deviation from usual grain production practices is greatest in the hill lands. Here deep tillage is infrequent, and a shallow cultivation or disking often replaces plowing. The seed may be broadcasted either before or after this simple preparatory treatment, and a final harrowing may, or may not, be given to complete the planting operation. This may be varied when weeds are abundant by dry plowing or cultivation followed by harrowing after the first rain to destroy weeds before planting (fig. 14). "Planting dry" before rain is more often practiced in hay than in grain production, partly because weeds are less objectionable in hay, and partly because early planting is more necessary for the production of high hay yields than for high grain yields. Summer fallowing is less frequent, but most of the land is pastured for from one to three years between hay crops. In the Cotati district a four-course rotation is followed, consisting of two successive oat hay crops, a wheat hay crop and finally a summer fallow. From 20 to 40 per cent of the grain hay producers in the hill lands of the

central coast counties practice summer fallowing, and the number increases to the southward in the drier regions of San Benito County. Occasionally, hay fields are rolled after planting, for the purpose of reducing clods, which in turn facilitates close mowing, and reduces the amount of dirt in the crop.

Such are the simple preparatory practices current in the hill hay lands of central California.

Time of Planting.—Throughout the cereal hay regions, early fall planting is essential to the production of high yields, and it is often advantageous to prepare the land "dry" and plant before the first rains in order to secure the advantages of an early fall growth. Oats are especially dependent upon early planting, and should be planted before the first of the year, except in the cool coast or mountainous regions. Wheat and barley are more tolerant of late planting than oats, but even these are generally greatly reduced in yield by late winter and spring planting. For planting upland soils after January 1, Chevalier barley is preferred to wheat or oats, but in dry spring seasons even this "heads short" and gives scanty yields. Good hay yields ordinarily cannot be expected from cereals planted after February 1, and if planting has been delayed until after that date and a hay crop is still desired, it is generally advisable to delay planting until about April 15, and then plant Sudan grass, provided there has been sufficient winter rains to insure a crop, and the soil has been stirred frequently enough to insure a mellow, moist seed bed at planting time. (See Calif. Bul. No. 277 "Sudan Grass"—revised edition 1923.)

Rate of Planting.—About 50 per cent more seed should be used when planting cereals for hay than when planting them for grain, because thick stands yield more and better hay than thin. Greater uniformity in stand and product may be effected by drilling the seed than by broadcasting it, and 25 per cent less seed is required. The optimum amount in any instance is initially a question of soil moisture, and the greater the amount of moisture, within certain limits, the thicker the stand the land is able to carry, and the greater the amount of seed it becomes advantageous to sow. It is recommended to drill 120 pounds of plump barleys, 100 pounds of plump wheat, and 90 pounds of heavy oats, when fall planting on well prepared average soils, in regions having a normal rainfall of 16 inches or more. With less than 12 inches of rain, and otherwise similar circumstances, these amounts should be reduced 25 per cent, or a similar reduction should be made for late (January and Feb-

ruary) plantings, which in effect reduce the total moisture supply available for the crop to draw upon during its life.

If broadcasting, on the other hand, from 25 to 30 per cent more seed should be used than when drilling under similar circumstances, and a cloddy seed bed will always require a more generous application of seed in order to secure a full stand than one finely prepared.

Fig. 14.—Covering broadcasted seed with the spring-tooth harrow. The seeding cart is visible on the hillside above. This is typical of the seeding practice in the steep hill lands of the cereal hay belt. Note that eight head of horses are required to pull "ten feet of harrow" and a riding sulky over the uneven ground.

MIXED CEREAL AND VETCH HAY

Mixed cereal and vetch hay is richer in protein than pure cereal hay, and more nearly approaches alfalfa in nutritive value, consequently it has been extensively utilized by dairymen in the unirrigated coast districts of northern California, where alfalfa does not thrive. Vetch, alone or in mixture, is also used for the improvement or range land, and extensively as an orchard cover crop throughout the fruit districts, but for the latter use, Purple vetch (*Vicia atropurpurea*), because of its more vigorous growth, is preferred, and seed for that purpose has been extensively produced in the Rhonerville-Hydesville district of the Van Duzen Valley of Humboldt County. Spring vetch (*Vicia sativa*), popularly known as Oregon vetch, is still the favorite hay variety among dairymen. The seed is imported mainly from the Willamette Valley of Oregon.

The most frequent difficulty in the production of mixed hay is that of obtaining a sufficiently vigorous growth of vetch in mixture with oats, and for this reason special precautions should be taken to insure the success of the vetch. Early fall planting is generally attended with better success than winter or spring planting, for the reason that vetch does not grow so vigorously as oats during the cold winter weather, and may be overtopped and crowded out if not given the advantage of early seeding. For this reason it is beneficial to drill the vetch about two weeks ahead of the oats, taking care to set the drill shallow for the oat seeding, in order not to disturb the vetch seedlings. The amount of oat seed sown in mixture should also be reduced to about one-half that used when planted for hay alone. A good mixture consists of 50 pounds of oats and 30 pounds of vetch per acre. The two kinds of seed may be mixed and drilled simultaneously, but separate drilling generally proves more satisfactory.

HAYMAKING

When to Cut.—Cereal hay if fresh in appearance, sweet smelling, and soft in texture, is of high market value, but to be of high feeding value it must also possess palatability and digestibility. These several attributes, collectively known as "quality," are functions of variety, climate, and production methods, including the all-important consideration of the stage of maturity at which the cereal is cut (fig. 15). The current opinion among Californian stockmen is that cereal hay of all varieties should be cut in the "milk" if intended for dairy cows, and in the "dough" if intended for stock cattle or horses, but that oat hay for driving or riding horses should be cut in the "milk," and barley hay for work horses should contain considerable ripened grain. It is held by some that barley awns lose their toughness, and therefore become less obnoxious in feeding when the barley is cut when nearly ripe. Rye must be cut in the "blossom" or earlier to yield hay comparable with the others in texture and palatability. The market requires that cereal hay be of bright color and good aroma, which necessitates early harvesting, but when grown for home consumption far greater latitude of harvesting and curing is practiced. Locality also tends to modify the practice in time of cutting. For example, when producing market hay in the drier interior districts, it becomes necessary to cut greener in order to avoid excessive bleaching, but cereal hay from the interior is nearly always of inferior market grade, partly because the product is intended

primarily for home consumption and therefore less carefully made, and partly because of the difficulty of curing perfectly and preserving natural color under the conditions prevailing. In the humid coast districts, on the other hand, bright natural color in cereal hay is also rare, because hay tends to assume a characteristic blackened color and unattractive appearance when cured in continuously foggy situations. In such places curing is also slower, and consequently it is advantageous to delay cutting until the plants have attained more advanced maturity, because they are then less succulent and cure more quickly. This is especially true of oats, because they are more leafy and succulent, and lose their moisture more slowly when bulked together in the windrow or cock. In the intermediate climate of the cereal hay belt, as typified by Sonoma, Contra Costa, and San Benito counties, cereal hays are cured under the most advantageous circumstances. The topography provides ideal soil and air drainage, the atmosphere is warm and dry but tempered by proximity to the sea, and in most places there are daily breezes which assist in the evaporation of moisture and hasten the curing process.

The best barley hay, as conceived by the trade, has a bright golden color, with considerable shriveled grain and brittle beards; the best red oat hay, a rich purple color with very little "filled" grain; and the best wheat hay, a pale green with some shriveled kernels. Rye hay should be pale green and contain no grain. A successful hay producer in San Benito County summarized his experience as follows: "Wheat should be cut in the 'milk,' just as the stalks turn creamy near the ground, but the remainder of the plant is green. Barley should be cut just as the stalk and head starts to turn a golden color, but while the leaves are still green. At this stage the heads will contain some grain. Oats should be green all the way down, but just starting to turn reddish at the bottom. Wild oats are best cut when between the 'milk' and the dough'."[5]

These views coincide with, and are unconsciously dictated by those of the wholesale hay trade, and hay cut as indicated and properly cured commands the highest market price. But as only a small proportion of the crop is marketed, the feeder is more concerned about the feeding value and the yield of his crop than about the arbitrary estimate of value placed upon it by the hay dealers. In the following pages some experimental findings bearing upon these questions are given.

Effect of Cutting Date Upon Yield.—To study the relation of maturity to yield, eight one-hundredth-acre plots of each of the

[5] Pacific Rural Press, vol. 95, p. 577—May 4, 1918.

four cereals were planted on November 7, and duplicate plots of each cereal harvested successively upon arrival at the "blossom," "milk," "dough," and "ripe" stages. The weights of air-dry hay from these successive cuttings are recorded in table 9.

TABLE 9

YIELDS OF CEREAL HAY AT SUCCESSIVE STAGES OF MATURITY

Stage cut	Average yield in tons per acre*			
	Wheat†	Barley†	Oats†	Rye†
Blossom	6.32	5.40	5.95	5.20
Milk	7.65	5.70	8.22	7.77
Soft dough	8.20	5.57	8.32	7.27
Ripe	7.42	4.40	7.35	7.22

* All lots of hay remained in cocks in the field from the time cut until weighed. The cutting time ranged from April 21 to June 9. During this period no rain fell. All lots were weighed June 19. During the curing period relative atmospheric humidities were very low, the mean ranging from 52 per cent to 62 per cent at 8 a. m., and from 38 per cent to 41 per cent at 5 p. m., with minimums as low as 21 per cent. The moisture content of the several lots at weighing time was uniformly low, averaging about 8.5 per cent (table 13).

† The varieties used were White Australian wheat, Coast barley, and California Red oats. The rye consisted of the mixed type grown in California.

The highest yield for each cereal was obtained at a stage of development intermediate between the "early milk" and the "late soft dough," but the exact stage giving the highest yield in each case was not accurately determined, and this appeared to vary with the different cereals studied. A considerable loss in tonnage was observed through cutting at the immature stage, represented as "blossom," and the actual losses between "milk" and "blossom" yields in tons per acre were as follows: barley .3, wheat 1.33, oats 2.27, and rye 2.57. There was likewise a loss in tonnage due to allowing the hay to ripen too completely before cutting, and the actual amounts lost in tons per acre between hay cut in the "soft dough" and that cut "ripe" were as follows: rye .05, wheat .78, oats .97, and barley 1.17. Although these losses were not so great as those sustained through too early cutting, it was found that rye, which lost most through early cutting, lost least through late cutting, and that barley, which lost least through early cutting, lost most through late cutting.

Each cereal increased in weight up to a stage of development peculiar to itself, and then underwent a diminution in weight as complete maturity was approached. This loss in dry matter in the latter stages of development was first called attention to, it seems,

by Isidore Pierre as cited by Perkins[6] in 1864, and subsequently by other investigators, notably by Perkins, et al.,[7] according to whom it is probably assignable to a translocation of mineral matter toward the root system as maturity advances, as well as to the more obvious shattering of ripe grain and leaves.

Number of Days to Make the Crop.—The varieties tested exhibited wide variability with respect to the hay ripening period, and during the 1918–1919 season under the conditions described on p. 16, the periods elapsing from planting to "soft dough" were as follows:

TABLE 10

NO. OF DAYS REQUIRED TO MAKE THE CROP

Coast barley	174
Chevalier barley	177
Nepal barley	177
Rye	187
Early Baart wheat	190
Sonora wheat	192
Little Club wheat	194
White Australian wheat	194
California Red oat	202
Wild oat	202
Velvet Don wheat	202
Coastblack oat	211
Roberts oat	226

In general, barley was earliest, rye and wheat with some varietal exceptions were intermediate, and oats latest. Velvet Don wheat was more nearly comparable with oats than with the other wheats, and most other durum wheats can be similarly classified.

The observations in table 11 indicate the approximate duration of the growth periods of the several cereals.

TABLE 11

GROWTH PERIODS OF WHEAT, BARLEY, OATS, AND RYE

Variety	Number of days to "blossom"	Number of days to "milk"	Number of days to "soft dough"	Number of days to "ripe"
White Australian wheat	177	192	194	213
Coast barley	161	169	173	201
California Red oat	173	189	201	214
Rye	161	184	186	210

[6] Wheaten Hay: Investigations as to What Stage of Development to Cut to Best Advantage. Dept. Agr. of So. Aust. Bul. No. 73. 1912.

[7] Further Investigations into Factors Affecting the Handling of Wheat Hay, Including a Study of Digestibility. Dept. Agr. So. Aust. Bul. No. 82. 1914.

There are several interesting relationships brought out here. It will be observed that Coast barley and rye both reached the "blossom" stage in 161 days, and approximately two weeks in advance of wheat and oats. Coast barley, however, reached the "milk" stage 8 days later, while rye required 23 days. In other words, the barley kernel "filled" much more rapidly after fertilization than that of rye. California Red oats required 16 days from "blossom" to "milk," and White Australian wheat 15 days.

Considering the time elapsing from "blossom" to "soft dough" as the "filling" period, we find the following relationship to have existed:

Coast barley	12 days
White Australian wheat	17 days
Rye	25 days
California Red oat	28 days

Effect of Cutting Upon Palatability.—Four lots of White Australian wheat hay—"blossom," "milk," "dough," and "ripe," were placed in separate feeding racks in the dairy barn corral at 11 in the morning of July 8, 1919, and 19 head of dairy stock given free and simultaneous access to them. At 8 the following morning the rack containing the "blossom" lot was entirely emptied, while the rack containing the other lots had been sampled but not eaten. The "blossom" hay, which the cattle had elected to eat first, had the best color, aroma and texture, but the heads contained no grain at all (table 12). By 8 in the morning of July 10, 46 hours after placing the hay in the racks, the "milk" hay had been about one-half consumed, the "dough" hay one-third consumed, but the "ripe" hay had been tasted but not eaten. By 8 in the morning of July 11, 69 hours after placing the hay in the racks, all of the "milk" and "dough" hay had been eaten, and a small amount of the "ripe" lot (less than one-tenth) had been eaten. On Monday morning, July 14, all of the "ripe" hay had disappeared.

From these observations, it becomes evident that dairy stock prefer White Australian wheat hay cut in the "blossom" to hay of the same variety cut at later stages of development, and that such hay becomes less acceptable as complete maturity is approached. Whether this order of preference would be shown for other varieties of wheat, or for barley, oats, and rye, has yet to be determined.

Effect of Cutting Date Upon Quality.—The percentage weight of component parts of the hay plant, such as stems, leaves, and heads, affords an exact means of comparing the physical composition of hays

of the same kind but of different degrees of maturity. This physical composition is closely correlated with palatability, chemical composition, and nutritive value. A sample of wheat hay, for example, cut in the "milk," and consisting of 14 per cent by weight of heads, would obviously possess qualities different from a second sample of the same variety cut "ripe" and consisting of 30 per cent of heads. The physical analyses appearing in the following table were made of samples taken from plots cut at successive stages of maturity to determine yields, and are distinct from those used in table 5, which were taken from another series of plots used to determine the relative *productiveness* of different varieties all cut in the soft dough.

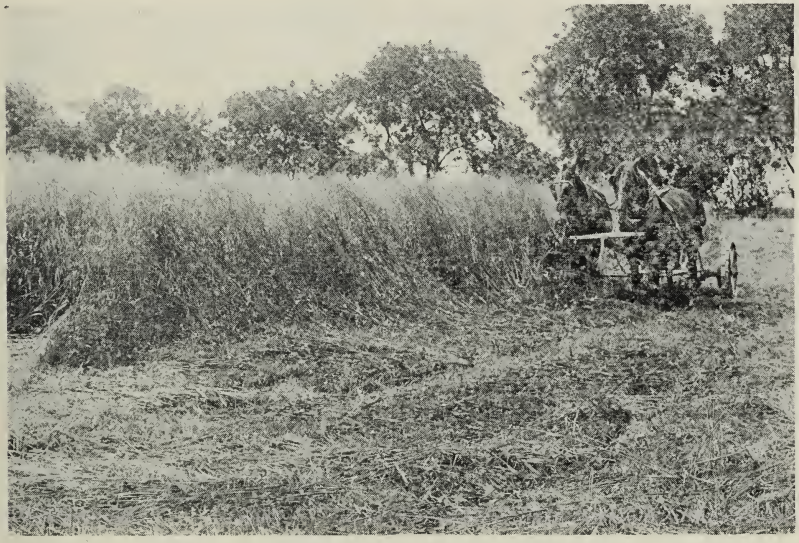

Fig. 15.—Mowing oat hay in Yolo County. Both the yield and the quality of any cereal hay is largely determined by the stage of maturity at which it is cut; but to realize the greatest possible value from the crop, both the response of the individual variety to time of cutting, and the special requirements of the particular kind of animals to consume it, must be considered. (pp. 48 to 51.)

From this study it appears that all cereals gained in percentage of head weight until the "soft dough" was reached and that wheat and barley continued to gain in head weight beyond that stage, while oats fell off slightly, and rye greatly, probably as a result of shattering. Diminutions in percentage of leaves by weight at successive stages of development are noted; the percentage of stalk (culm) is less regular, but appears to increase slightly from "blossom" to "milk" or "dough" in wheat and barley, with subsequent diminutions, to remain constant in oats, and to increase with maturity in rye.

Wheat loses its green color more quickly as maturity is approached than rye, and when cut well toward maturity fades more than rye. Samples taken in the "milk" and "dough" become pale green, and those taken near maturity lose their green coloration completely.

Barley retains an attractive green color until the "early dough" stage, but since its maturation period is very short (table 11), the actual time during which it may be "cut for color" is very short.

TABLE 12

Effect of Cutting Date Upon Physical Composition

Variety	Stage of development cut	Per cent by weight of culms (stems) cut 4 inches above root and one inch below head	Per cent by weight of leaves including sheath	Per cent by weight of heads including grain
White Australian wheat	Blossom	44	42	14
	Milk	41	42	17
	Soft dough	47	34	19
	Ripe	44	26	30
Coast barley	Blossom	40	38	22
	Milk	42	31	27
	Soft dough	38	27	35
	Ripe	29	24	47
California Red oat	Blossom	41	42	17
	Milk	43	30	27
	Soft dough	38	25	37
	Ripe	41	25	34
Rye	Blossom	50	33	17
	Milk	59	22	19
	Soft dough	56	23	21
	Ripe	60	26	14

California Red oat hay retains the best natural color when cut in the "milk," but often retains a soft texture when cut well on toward maturity.

Rye hay becomes very tough and unpalatable toward maturity, and should be cut in the "blossom" or earlier in order to compare favorably with the other cereals in palatability. Rye retains its green color into advanced stages of maturity, later perhaps than any of the other cereals, a circumstance which illustrates that color alone is not an infallible index to quality.

Effect of Cutting Date Upon Chemical Composition.—Composite samples, consisting of several plants, were taken of wheat, barley, oats, and rye at successive stages of maturity, and prepared for chemical analysis by curing indoors under comparable conditions, and the roots with about four inches of the culms discarded before chopping for analysis. The results of these analyses are summarized in table 13.

TABLE 13

EFFECT OF CUTTING DATE UPON CHEMICAL COMPOSITION*

Variety	Stage of development cut	Per cent moisture	Per cent ash	Per cent protein	Per cent fat	Per cent crude fiber	Per cent carbohydrates
White Australian wheat	Blossom	8.0	8.7	5.8	2.1	34.6	40.8
	Milk	7.2	8.9	6.9	1.2	33.3	42.5
	Soft dough	8.0	8.4	6.8	1.0	31.1	44.7
	Ripe	8.0	5.7	5.7	.9	38.0	41.7
Coast barley	Blossom	8.7	6.3	8.0	1.6	28.0	47.4
	Milk	9.7	5.0	9.1	1.7	25.8	48.7
	Soft dough	9.0	5.3	8.6	2.2	23.3	51.6
	Ripe	8.7	4.7	7.4	2.4	23.8	53.0
California Red oat	Blossom	8.3	5.3	8.4	1.8	31.6	44.6
	Milk	9.3	5.7	6.6	2.5	34.3	41.6
	Soft dough	10.0	3.7	6.1	2.5	29.7	48.0
	Ripe	8.0	5.3	5.7	1.9	33.4	45.7
Rye	Blossom	7.7	6.0	9.8	1.5	42.4	32.6
	Milk	9.3	4.7	7.3	1.7	34.4	42.6
	Soft dough	7.7	5.0	8.4	1.7	33.6	43.6
	Ripe	7.7	8.0	4.7	1.7	41.0	36.9

* Analyses by J. H. Norton, Instructor in Chemistry, and R. J. Slama.

In these analyses the following points are brought out:

1. The percentage of moisture has not been influenced in any regular manner by the stage of maturity of the crop when cut.

2. The percentage of ash or mineral matter has shown a tendency to decline as maturity is approached.

3. The proteins are less abundant in the advanced stages of development than in the immature stages, and showed a falling off in all cases from "soft dough" to "ripe."

4. There appears to be very little difference in the proportion of fat present in hay of the same kind cut at different stages of maturity.

5. The percentage of crude fiber was highest in rye and lowest in barley, and increased in all cereals from "soft dough" to "ripe."

6. The percentage of carbohydrates showed an increase in all cereals from "blossom" to "milk," except in the case of oats, and a decrease between "soft dough" and "ripe" in all cereals except barley.

The above evidence confirms the current opinion that barley, wheat and oats should be cut in the "milk" when intended for dairy cattle or saddle horses, and in the "soft dough" when intended for work horses, mules, or stock cattle. Rye should be cut in the "blossom" or earlier for all purposes.

CURING

There is a great difference between well cured hay and mere sun-dried fodder, although both may be made under similar conditions. One has been protected from the direct rays of the sun by proper manipulation in the windrow, cock and stack, while the other has been left exposed in the swath or windrow until dry and bleached. The leaves of one have remained alive long enough to transpire naturally a large percentage of the moisture from the stems, while the leaves of the other have died quickly from exposure, thereby checking the biological processes, known as fermenting, heating, and sweating, which commonly occur in the cock and stack, and which are essential to the perfect curing of hay.

One possesses a fine lavender-like aroma, is soft and pliable, and appetizing to stock, while the other would not be eaten by well fed animals and would serve merely to keep cattle from starvation.

Curing may be said to commence the instant the crop falls behind the mower, and to continue, when properly carried out, for six weeks. When cut, the crop may consist of 75 per cent of moisture, and when fully and perfectly cured from 15 to 20 per cent, or even as little as 8 per cent when shock cured in an arid climate, but curing is more than a mere mechanical drying, and cannot be accelerated beyond certain limits without injury to the quality of the hay.

The initial step of wilting may occur within an hour or two under the influence of a hot sun and dry atmosphere, but usually several hours of bright sunshine are required, and occasionally, in humid localities, the crop must lie in the swath two or more days before it has lost sufficient moisture to be safely raked. The usual assumption is that a crop mown in the morning during fair weather may be raked in the afternoon, but in any event the crop should not be left

in the swath longer than is essential to the loss of sufficient moisture to permit of its being raked into windrows. Hay should never be raked when damp with dew or fog, and in the coast districts it is well understood that the mower should not be sent into the field in the morning until the sun has dried the fog from the leaves.

Raking into windrows is the first step in the curing process, and is indispensable in the bulking together of the crop. Hay should not remain in the windrow longer than is necessary, and under average climatic conditions two or three days in the windrow is long enough; but in the dry climate of the Great Valley cocking generally may, and should follow raking almost immediately, leaving the crop in the windrow only long enough to bunch it. Experienced producers consider windrowed cereal hay dry enough to cock when it rattles slightly upon being disturbed with the foot. If left in the windrow longer than necessary, there is too great exposure to sunlight, the leaves die, and the curing process is cut short.

The cock, or shock (fig. 2) affords greater protection than the windrow (fig. 3), and prolongs the curing process; but since it does not afford perfect protection, hay should remain in the shock only long enough to prepare it for the stack. Under average conditions this requires about two weeks. A simple test to determine the fitness of the crop for baling or stacking consists of taking a wisp from near the center of the shock near the ground and twisting it tightly between the hands, like wringing a cloth. If visible traces of moisture remain on the hands, the crop is considered too moist to bale or stack. Another test is to break the stems at the joints, and if they have become dry enough to snap the crop may safely be stacked or baled.

If hay is to be baled directly from the shock without stacking, the shocks should be made large, from 800 to 1200 pounds in each, in order to provide greater protection and prolong the curing process. Hay does not cure completely in the shock, however, even in large shocks, because it loses its moisture too rapidly; and for this reason, if it is to be stacked, this should be done while the hay is still moist enough to fully complete the curing processes in the stack.

STACKING

The curing process is carried to completion in the stack, where, if sufficient moisture is present, sweating, heating, and fermentation may continue for from four to six weeks, imparting to the hay its richest aroma and softest texture, at the same time diminishing the fiber content, and increasing the relative amount of nitrogen free

extract and other nutrients. Morever, "stack-cured" hay, because of its greater uniformity in color and moisture content, presents a more attractive appearance when baled than "shock-cured" hay.

But only a small part of the Californian cereal hay crop is stacked before baling, and this originates chiefly in the San Francisco Bay region and about Hollister. It supplies special markets requiring hay of the highest quality, such as riding academies, eastern racing stables, and the United States Army.

To facilitate baling, each stack should contain not less than 25 tons, or sufficient to supply one "setting" of the press, and should be built at right angles to the direction of the prevailing wind, on level ground in the open field. A high, narrow stack, not more than 20 feet in width, is more conveniently baled and with less labor than a broader one. The unstacking process is more easily accomplished if each load is well distributed over the surface upon arrival, rather than piled a load in a place. A good stacker moves about the stack constantly and always keeps the center higher than the sides. Stacks made in this way shed the rain more effectively, cure more uniformly, pitch into the press more easily, and pack more compactly and uniformly in the bale than those made less systematically.

Many experienced producers also maintain "off-grade" stacks, to which all weedy shocks are diverted, and also exercise care in separating clods from the bunches as they arrive at the stack.

ESTIMATING TONNAGE IN STACKS

The rules for calculating the volume of hay stacks correspond to those employed in calculating of volume of solid bodies generally. The volume of one ton of stacked cereal hay depends upon its age, condition, and variety. Freshly stacked cereal hay may vary from 540 to 590 cubic feet per ton; the same hay after 80 days of settling may measure only from 510 to 540 cubic feet per ton; and when old and fully settled as little as 421 cubic feet may weigh one ton. The rules in general use for estimating the tonnage content of stacks are given below:

The Frye-Bruhn Rule.—This rule, named after the Frye-Bruhn Company of Seattle, has come to be widely used in the western states, but it is accurate for one shape of stack only, namely, one with a cross-section similar to that represented by No. 7, fig. 16. That is, low, with comparatively high sides and flat crown. It has has been found to overestimate by about 1 per cent higher, fuller stacks, such as are represented by No. 8, fig. 16, and to overestimate by

about 7 per cent very high, full stacks, such as are represented by No. 9. For the other six shapes, represented in fig. 16, it varies from 2 per cent to 17 per cent too low.

Rule.—Multiply the width in feet by the length in feet, by one-half the difference between the "over" in feet and width in feet, and divide the product by 512; the quotient will be the estimated number of tons of hay in a three-month-old stack.

$$\textit{Formula.}—\frac{W \times L \times \tfrac{1}{2} (O - W)}{512} = \text{No. of tons in stack.}$$

In the above formula, W = width in feet, L = length in feet, and O = over in feet, or the distance from the ground on one side straight over the stack to the ground on the other side.

Example.—How many tons of hay in a three-months stack, 45 feet long, 24 feet wide, and 120 feet over?

$$\textit{Solution.}—\frac{24 \times 45 \times \tfrac{1}{2} (120 - 24)}{512} = 101.+ \text{ tons.}$$

The Quartermasters' Rule.—This rule, sometimes referred to as the Government Rule, is accurate for one shape of stack only, namely, that with a cross-section similar to that represented by No. 7, fig. 16; that is, low, with comparatively high sides and flat crown. It underestimates from 1 per cent to 2 per cent stacks of the shape represented by Nos. 5 and 6, and may vary from 13 per cent too low to 12 per cent too high for the other shapes represented in fig. 16.

Rule.—Add the "over" and "width," and divide by 4; multiply the result by itself, and then by the length, and divide by 512.

$$\textit{Formula.}—\frac{\left\{\frac{O + W}{4}\right\}^2 \times L}{512} = \text{No. tons in stack.}$$

In this formula O = "over," W = width, and L = length.

Example.—How many tons of hay in a three-month old stack, 45 feet long, 24 feet wide, and 112 feet "over"?

$$\textit{Solution.}—\frac{\left\{\frac{112 + 24}{4}\right\}^2 \times 45}{512} = 101.+ \text{ tons.}$$

*The Department Rule.**—"The volume of a stack is equal to its length multiplied by the area of its cross section. The length is easily measured. Let us consider the principles involved in measuring the area of the cross section. If the top of the stack were prefectly flat, and the two sides straight up and down, the area of the cross section would simply be the width multiplied by the height. If the stack

* This rule was devised by McClure and Spillman of the U. S. Department of Agriculture, and is taken from Circular No. 67 of the Office of the Secretary, U. S. D. A., Dec. 9, 1916. It is the most accurate and generally applicable of the rules here given.

were triangular in cross section, so that the sides represented straight lines from the top of the stack to the bottom on each side, the area of the cross section would be one-half of the product of the base and the height. The actual area of the cross section lies somewhere between these two.

It is difficult to measure accurately the height of a stack. It is much easier to measure the "over," which is the distance from the ground on one side of the stack over the top of the stack to the ground on the other side. The length of the "over" depends upon three things: (1) width, (2) height, and (3) "fullness" of the stack. The "over" is always somewhat more than twice the height.

It has been found by actual measurement that the cross section of a stack is the product of the "over" and the width, multiplied by a fraction varying from 0.25 to 0.37 (average value, 0.31), according to the height and fullness of the stack. If the stack is low in comparison with its width and nearly triangular in outline—that is, its sides are not very full—the fraction is small (0.25). If the stack is tall in comparison with its width, and the sides are very full, so that the top is well rounded, the fraction is large (0.37). Representing this fraction by F, the over by O, the width by W, and the length of the stack by L, the volume being represented by V, we have the following formula for determining the number of cubic feet in a stack:

Volume = *Fraction* x *Over* x *Width* x *Length or*, as commonly written,

$$V = FOWL$$

The fact that the right-hand member of this formula spells the word "fowl" makes it easy to remember.

Figure 16 shows the cross sections of haystacks of nine different shapes, the corresponding value of the fraction F for each of these shapes being inserted in the outline of each cross section. The height of stacks Nos. 1, 4, and 7 (upper row) is three-fourths the width. The height of stacks Nos. 2, 5 and 8 (middle row) is equal to width, while the height of stacks Nos. 3, 6, and 9 (lower row) is one and one-fourth times the width. Stacks Nos. 1, 2 and 3 (left column) are narrow or nearly triangular in outline; stacks Nos. 4, 5, and 6 (middle column) are medium full, while stacks Nos. 7, 8, and 9 (right column) are full and rounded. It will be noticed that the value of F is the same (0.31) in Nos. 3, 5 and 7; in Nos. 2 and 4 it is (0.28), and in Nos. 6 and 8 (0.34).

In attempting to find the volume of haystacks the choice between these various values of F may be found by comparing the shape

of the end of the stack—that is, the cross section of the stack—with stacks Nos. 1 to 9 in figure 16. If the shape of the stack to be measured is intermediate between those shown in figure 26 intermediate values of F may be used. The use of the above formula may be made clear by a few examples.''

Example 1.—A haystack is 16 feet wide, 24 feet long, and the over is 31.2 feet. The end view indicates that the shape of the stack is very close to No. 4 in figure 26. What is the volume of the stack.

Solution: $V = 0.28 \times 31.2 \times 16 \times 24 = 3354.+$ cubic feet.

Example 2.—A haystack is 14 feet wide, 20 feet long, and the over is 34.2 feet. Inspection of the end of the stack shows that it is of the type of No. 8 in figure 26. What is the volume of the stack?

Solution: $V = 0.34 \times 34.2 \times 14 \times 20 = 3255.+$ cubic feet.

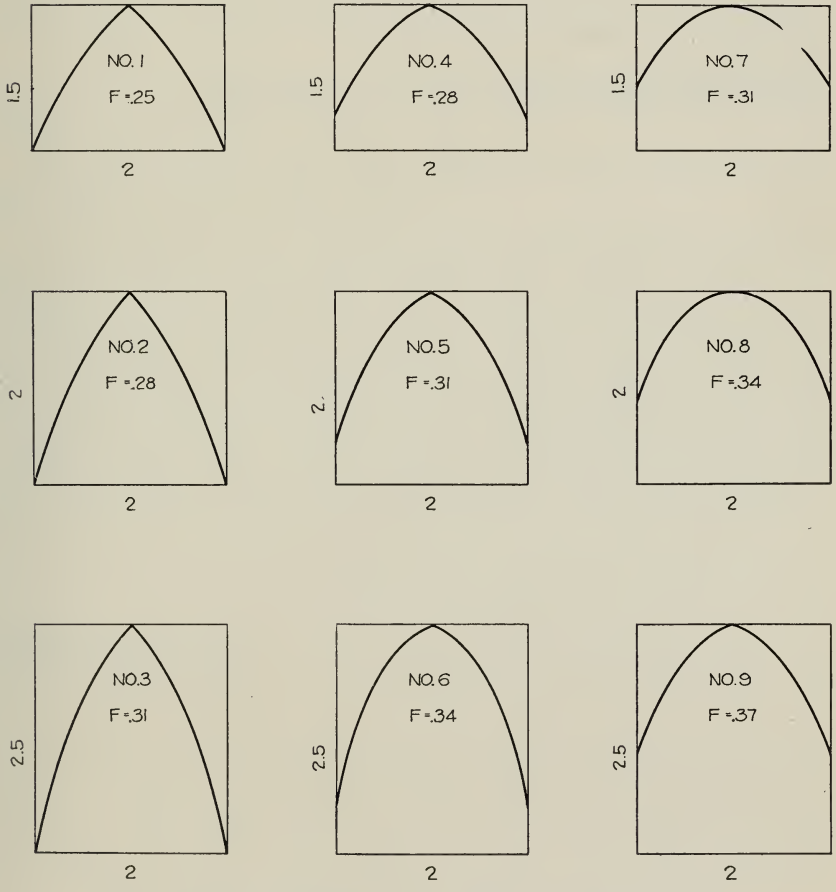

Fig. 16.—Cross sections of hay stacks of different shapes. (After McClure and Spillman.)

Estimating Round Stacks.[8]—"There is no established rule for measuring round stacks, but this one will approximate the contents of a stack of ordinary conical form. Find the circumference at or about the base or 'bulge,' at a height that will average the base from there to the ground; find the vertical height of the measured circumference from the ground, and the slant height from the measured circumference to the top of the stack, taking all measurements in feet. Multiply the circumference by itself and divide by 100 and multiply by 8, then multiply the result by the height of the base, plus one-third of the slant height of top." This will give the estimated volume of the stack in cubic feet. To estimate the tonnage, divide by the number of cubic feet in a ton. The hay in a round stack is usually less compact than in a rectangular stack, hence a greater number of feet should be allowed for a ton, with well-settled hay probably 512 cubic feet.

[8] Kans. Agr. Exp. Sta. Bul. No. 155, p. 259. June, 1908.

II. FEEDING TRIALS WITH CEREAL HAYS

F. W. WOLL*

Three series of feeding trials with grain hays were conducted at the University Farm during 1919 and 1920, as follows:

I. In the summer of 1919, with grain hay grown at the University Farm in the field trials described in the preceding pages, namely: with three varieties of barley hay, and one variety of rye hay.

II. During January to March, 1920, with one lot each of wheat hay and of oat hay, purchased in the open market as representative lots of No. 1 grade hay.

III. During the summer of 1919, with one variety each of wheat, rye, oat and barley hay grown at the University Farm in the field trials described in the preceding pages.

The three feeding trials will be described in the order given and the results secured briefly discussed.

First Feeding Trial, June-July, 1919.—The trials were conducted with seven lots of four dairy heifers each, ranging in age at the beginning of the trials from nine to thirty-three months old, and in body weight from 560 to 1172 lbs. Each lot was composed of one Jersey heifer and either three Holstein heifers, two Holstein and one Ayrshire, or two Holstein and one Guernsey, the aim being to make the different lots as similar as possible as to breed, age, and body weight. The average initial age and weights of the different lots at the time the trials were planned on June 2d were as follows:

	Lot I	Lot II	Lot III	Lot IV	Lot V	Lot VI	Lot VII
Average age, months	24	20	19	21	22	21	18
Average weight, pounds	857	860	853	879	864	863	853

The lots were kept in adjoining corrals west of the University dairy barn (fig. 17), where they had access to fresh drinking water and salt. Each lot was fed one kind of hay as sole feed throughout the trials. This was placed in the racks at the beginning of the experiment, the racks being filled as needed. When the supply of

* Died Dec. 5, 1922.

one kind of hay was all gone, the amounts of hay remaining in the other racks or in the stacks were weighed back. The following kinds of cereal hay were fed in the trials:

Barley hay: Coast, Chevalier, and Nepal.
Oat hay: California Red, Coastblack, Roberts, and Wild.
Wheat hay: White Australian, Little Club, Sonora, Early Baart, and Velvet Don (durum).
Rye hay: California.

Seven of the grain hays, namely, three barley and four oat hays, were fed in the first period of the trials, June 17 to July 2, and six hays, namely, five wheat and one rye, were fed during the second period, July 19 to 26. The heifers received an average ration of about 32 lbs. of green alfalfa and 10 lbs. of sorghum silage a day previous to the beginning of the first period, and alfalfa hay was fed during the week intervening between the two periods. They were weighed the first time on June 2, and again on two successive days at the beginning and the end of the trial; also once at the middle of each period.

It is not possible under the method of corral feeding practiced to differentiate between the amount of hay actually eaten by the stock and that wasted by being pulled out of the racks and trampled upon on the ground. A careful estimate of the amount of hay wasted was, however, made at the end of each period, and the different hays were accordingly placed as follows, in order of decreasing amounts of waste: California Red oat, Coastblack oat, Nepal barley, Roberts oat, Coast barley, Chevalier barley, and wild oat. The preceding order of waste may not be absolutely correct, but the following classification is doubtless reliable and may be taken as an indication of relative palatability:

Light waste: Wild oat, Chevalier barley.
Medium waste: Coast barley.
Heavy waste: Roberts oat, Nepal barley, California Red oat, Coastblack oat, and rye.

Chemical analyses of samples of the cereal hays fed were made by Mr. J. H. Norton, with the results as shown in table 14.

It will be noted from the data presented that considerable differences occurred in the chemical composition of the different kinds of grain hay, but that the average composition of these did not differ materially as regards total components. Owing to the lack of digestion trials with different varieties and kinds of grain hays, the amounts of digestible components present in each cannot be definitely stated, and any estimate of such would be of doubtful value in view

of the variations in the composition and physical appearance of the different hays. Considering the total amounts of the various feed components in the grain hay, it may be noted, however, that barley hay is, on the average, higher in protein than any of the others, rye and Velvet Don hay coming next, with oat and wheat hay lowest. The average fiber contents increased in the following order:

TABLE 14

CHEMICAL COMPOSITION OF CEREAL HAYS IN PERCENTAGES

	Moisture	Protein	Fat	Fiber	Starch, sugar, etc.	Ash
Barley:						
Chevalier	9.0	8.1	1.6	29.3	44.3	7.7
Coast	7.7	10.1	1.5	31.6	42.1	7.0
Nepal	8.0	7.4	2.0	26.8	48.8	7.0
Average	8.2	8.5	1.7	29.2	45.2	7.2
Oats:						
California Red	8.0	6.2	2.7	27.6	50.2	5.3
Coastblack	6.3	6.9	2.3	38.1	41.1	5.3
Roberts	5.7	7.1	1.8	37.7	41.7	6.0
Wild	6.0	5.8	2.1	33.3	46.8	6.0
Average	6.5	6.5	2.2	34.2	45.0	5.6
Wheat:						
White Australian	7.0	5.2	1.5	30.5	48.8	7.0
Early Baart	8.7	6.7	1.0	31.0	44.8	7.8
Little Club	7.7	6.0	2.2	34.6	42.5	7.0
Sonora	7.7	6.6	.5	31.1	47.0	7.0
Average	7.8	6.4	1.3	31.8	45.8	6.9
Velvet Don	7.3	7.4	2.2	32.9	44.5	5.7
Rye	8.3	7.4	2.3	34.1	42.6	5.3

oats, rye, Velvet Don, wheat, and barley hay. The average fat content of rye, Velvet Don and oat hay differed but slightly, and was higher than that of barley and wheat hay, while the group known as nitrogen-free extract (starch, sugar, etc.) decreased as follows: wheat, barley, oats, Velvet Don, and rye hay.

On the basis of the results of the chemical analyses alone, without considering the digestibility of the various kinds of hay, one would be justified in placing barley as the most valuable hay from the feeder's point of view, on account of its high protein and starch contents and its low fiber content. Wheat was next, and oat and

rye as least valuable. The variations in chemical composition are, however, not marked, and the number of analyses small, so that general conclusions on this point cannot be safely drawn, and the preceding comparisons as to relative feeding value can only be considered suggestive.

Table 15 shows in summary the results obtained as regards the amounts of hay eaten, the gains in body weight of the heifers, the amount of hay eaten (or wasted) per pound of gain in body weight, and the gains made per hundred pounds of hay.

TABLE 15

SUMMARY OF RESULTS IN FEEDING TRIALS FOR 1919

Hay fed	Amount eaten		Gain in body weight		Rank	Hay eaten (and wasted) Per lb. gain, lbs.	100 lbs. hay produced		Rank
	Total, lbs.	Per head per day, lbs.	Per lot, lbs.	Per head per day, lbs.			Gain in weight lbs.	Gain per acre, lbs.	
Coast barley	1129	18.8	5.3	.35	6	53.7	1.9	17.1	7
Chevalier barley	996	16.6	7.7	.51	5	32.5	3.1	29.1	6
Nepal barley	1199	20.0	− 3.2	− 2.1	9				
California Red oat	1611	26.9	−18.8	−1.25	12				
Coastblack oat	1649	27.5	−32.0	−2.13	13				
Roberts oat	1569	26.1	− 1.8	− .12	8				
Wild	1107	18.4	−14.5	− .97	10				
White Australian wheat	1246	17.3	25.2	1.40	2	12.4	8.1	1142.1	1
Little Club wheat	1233	17.1	13.5	.75	4	22.8	4.4	576.4	4
Sonora wheat	1444	20.6	26.2	1.46	1	14.1	7.1	891.8	2
Early Baart wheat	1323	18.4	18.7	1.04	3	17.7	5.7	769.5	3
Velvet Don wheat	911	12.7	−19.0	−1.06	11				
Rye	1709	23.7	5.4	.30	7	79.0	1.3	177.6	5

From one to three of the animals in all but two lots, those fed Sonora and White Australian wheat hay, lost weight during the progress of the trials; and in the lot fed Coastblack oats all the animals lost weight. Gains in body weight of forty pounds or over were made by heifers fed Early Baart, Sonora, White Australian wheat hay, and Chevalier barley; on the other hand, heifers fed Nepal barley, Coastblack oats, Velvet Don, and wild oat hay lost over 40 pounds each during the feeding period. On the average for each lot, gains in body weight were made in decreasing order as follows: Sonora (average 1.46 lbs. per head daily); White Australian, Early Baart, Little Club wheat hay, Chevalier and Coast barley hays and rye hay (.30 lbs. gain). The lots that lost weight on the average were

as follows, in increasing order: Roberts oat (.12 lbs. per head daily), wild oat, Velvet Don (durum) wheat, California Red oat, Nepal barley and Coastblack oat (2.13 lbs.).

The outstanding feature of the trials, therefore, is that the four wheat varieties ranked highest for production of body weight, when fed under the conditions of these trials, with Coast and Chevalier barleys and rye following in the order given. Considering the economy of the hay feeding and the gain made per hundred pounds of hay, the wheat varieties were decidedly ahead of the other grain hays mentioned. All produced a net average gain in body weights, while all varieties of oat hay, Velvet Don, and Nepal barley, failed to produce any gain in weight during the trials. The further discussion of the results obtained in these trials will be postponed until the other two feeding trials conducted during the second year have been described and the results obtained presented.

Second Feeding Trial, January to March, 1920.—In view of the importance of cereal hay as a stock feed to the farmers of the state, and of the lack of reliable information as to the value of different hays for the various classes of livestock, it was decided to repeat the trials with grain hays grown at the University Farm during the following year. It was felt that the poor showing made by the oat hays might be due to the fact that this locality, the lower Sacramento Valley, is not particularly adapted to the growing of oat hay, and that the results with oat hay grown in localities where oats do especially well, and where considerable quantities of oat hay are raised normally, might be different. It was, therefore, decided to purchase a quantity of standard wheat hay and oat hay on the market, and to feed these hays to a dozen yearling heifers at the University Farm during January to March, 1920. The plan of the trials provided for feeding the hays during two periods of four weeks each to two lots of heifers, wheat hay to be fed to one lot during the first period, and oat hay to the other lot. During the second period the lots were to be reversed, wheat hay being fed to the lot receiving oat hay during the first period, and *vice versa*. A week's preliminary feeding preceded each period in order to accustom the animals to the feed.

Twelve dairy heifers, namely, 4 pure-bred Jerseys, 3 pure-bred and 2 grade Holsteins, 1 pure-bred and 1 grade Ayrshire, and 1 pure-bred Guernsey were available for this trial. The heifers ranged in age from 14 to 32 months, and in weight from 612 to 1080 lbs. at the beginning of trial. They were separated into two lots that were made as uniform as possible as to breed, age, weight, and general

thriftiness. The average ages of the lots were 19 and 20 months for lots A and B, respectively; the average weight of the heifers in lot A was 819.7 lbs., and of those in lot B, 820.3 lbs. The animals were fed in corrals adjoining the dairy barn on the west, in a way similar to that of the previous season's trials. They were weighed off dry feed on two consecutive days, at the beginning and also at the end of each period.

Both the wheat hay and the oat hay were grown in Sonoma County and were purchased of an Oakland firm. A botanical examination of the hays made by Hendry gave the following results:

The wheat hay was of a bright pale green color, consisting of about 75 per cent White Australian and 25 per cent mixed Little Club and Early Baart. The hay had been cut when the Australian variety was in the "late milk" and the hay of this variety and Little Club contained small shrunken kernels. The Early Baart variety, on the other hand, being a more early maturing variety, was more advanced when cut, the hay contained a higher percentage of grain, and the kernels were about half formed. Evidently, the Early Baart was in the "soft dough" when cut.

The oat hay consisted of the common California Red or Texas Red variety, and was of a bright color, well cured and of good quality. It had the characteristic reddish purple color of the variety. It was in the "late dough" when cut, and the kernels for the most part were well filled. On the whole it was slightly more advanced as to maturity than the sample of wheat fed in comparison.

Both hays were No. 1 grade hay and of good quality. The wheat hay would probably have had a better grade on the market had it been cut earlier, and had been of a greener color.

The feeding trial commenced January 7 and ended on March 17. The results obtained in the trial as shown in table 16.

TABLE 16

SECOND FEEDING TRIAL

	Wheat hay			Oat hay		
	Lot A Per I	Lot B* Per II	Total	Lot B* Per I	Lot A Per II	Total
Hay eaten, lbs.	3420	2738	6158	3125	3795	6920
Average per head, daily	20.4	19.6	20	22.3	22.6	22.5
Average initial body weight	837.5	823.4		787.2	885.3	
Total gain in weight	38.8	7.6	46.4	35.8	5.7	41.5
Average daily gain, lbs.			.83			.74

* Average for 5 animals.

One of the heifers included in lot B freshened earlier than expected, namely, March 2, and the data given for this lot therefore include those for five animals instead of six, the number comprising lot A. The stock ate the hay much more readily in the beginning of the feeding periods than toward the end. This applies to either kind of hay, and is very probably the result of the one-sided diet which the heifers received. Considerably greater gains in body weight were made by each lot during the first period than during the second, the decrease in gains made by animals going from wheat hay to oat hay being greater than for those receiving wheat hay during the

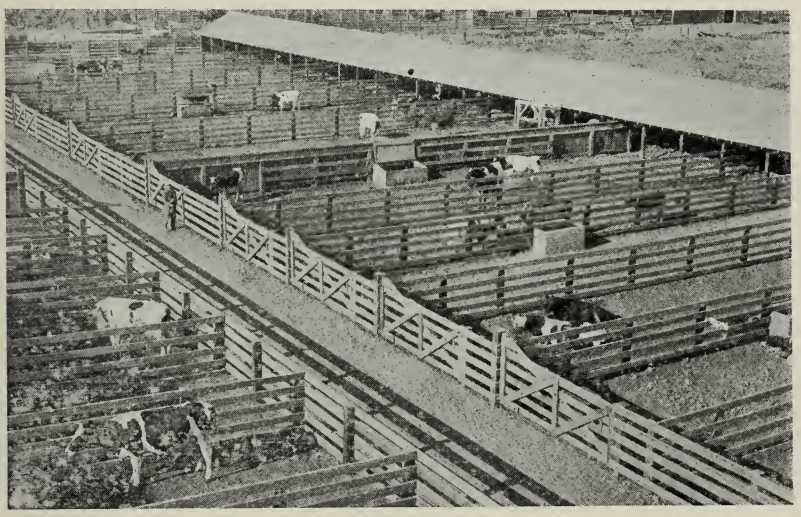

Fig. 17.—Feeding trials in progress *at Davis*. The outstanding generalization arising from three separate cereal hay feeding trials at Davis has been: that the nutritive effect of oat hay, fed as a sole ration to dairy stock, is considerably lower than that of wheat, barley, or rye hay. (p. 59.)

second period. The smaller heifers ordinarily did not get to the feed racks until the larger ones had had their fill, and made, in general, smaller gains. The condition and general thriftiness of the heifers at the close of the trial, as a result, as judged by their external appearance, differed considerably.

There was apparently but little difference between the two kinds of hay as regards waste of feeding; it would seem as though this depends more on the manner of feeding the hay in the racks, and the amounts fed at a time, than on the kind of hay fed. In these trials the hay was put before the animals each day in such quantities as they would be likely to clean up each time. Good weather prevailed throughout the trials, although these were conducted during the

rainy season, and the conditions in this respect were therefore favorable to securing uniform results. The data presented in the table show that the average amounts of hay eaten by the heifers during the trials were 20.0 lbs. of wheat hay and 22.5 lbs. of oat hay per day, and that the daily gains in body weight averaged .83 and .74 lbs. per day for wheat hay and oat hay rations, respectively. In spite of the larger amount eaten, the animals therefore did not gain so much on oat hay as on wheat hay. Calculated upon 100 lbs. of hay eaten, an average gain on wheat hay amounting to 4.15 lbs. was secured, and on oat hay 3.29 lbs., indicating a difference in nutritive effect of close to 25 per cent in favor of the wheat hay as compared with oat hay.

Third Feeding Trial, August to October, 1920.—Four varieties of grain hay were grown at the University Farm during 1920 for the purpose of further study of the yields and feeding value of standard California grain hays, as reported in the preceding pages. The hays used in the feeding trials were transferred to the corral west of the dairy barn, where they were stacked. The hay was hauled from the stacks as needed, 100 to 200 lbs. at a time, and placed in the feed racks before the stock.

Twenty-four yearling heifers were available for the trial. They were separated into four lots of six each, in such a way that the lots were as uniform as possible as to average age, weight, breed, etc. The trial commenced August 25, 1920, and was continued for eight weeks, separated into two periods of four weeks each. The different lots were fed grain hay only, as follows, during the progress of the trial:

Period I.	Period II.
August 25 to September 22	September 22 to October 20
Lot I.—Barley hay	Wheat hay
Lot II.—Wheat hay	Barley hay
Lot III.—Oat hay	Rye hay
Lot IV.—Rye hay	Oat hay.

Amounts of Feed Eaten.—The amounts of feed eaten during the third trial, and the gains in body weight made by the different lots during the two periods are shown in table 17.

The results presented in the table show that about 6000 lbs. of wheat and oat hay, about 5000 lbs. of barley hay, and 5600 lbs. of rye hay were eaten by the heifers during the entire trial. The total gains made by the lots fed wheat and rye hay were practically equal, namely, 217 and 220 lbs., while during the barley hay periods the animals gained a total of 183 lbs., and during the oat hay

periods 54 lbs. only. The superiority of wheat hay over barley and oat hay was therefore again demonstrated in these trials, and it is noteworthy that the gains made by the animals on the oat hay were only one-fourth that secured by either wheat or rye hay. Small losses in weight occurred in individual animals during all periods and on all grain hays, except in the cases of barley hay during Period I, and rye hay during period II.

TABLE 17

THIRD FEEDING TRIAL

	Barley		Wheat		Oats		Rye	
	Hay, lbs.	Gain in weight, lbs.	Hay, lbs.	Gain in weight, lbs.	Hay, lbs.	Gain in weight, lbs.	Hay, lbs.	Gain in weight, lbs.
Period I	2530	165	3205	105	3235	14	2775	196
Period II	2550	18	2800	112	2800	40	2840	24
Total	5080	183	6005	217	6035	54	5615	220
Pounds hay per pound gain	27.8	.....	27.6	.....	111.8	.....	25.5	.....

The chemical analyses of the different kinds of hay fed in these trials, as determined in the Nutrition Laboratory in Berkeley through the kind assistance of Professor M. E. Jaffa, gave the results shown in table 18.

TABLE 18

CHEMICAL COMPOSITION OF GRAIN HAYS, IN PERCENTAGES

	Rye	Wheat	Oats	Barley
Moisture	13.94	15.11	15.29	15.35
Protein	5.05	6.59	6.93	6.75
Fat	2.01	2.17	2.34	1.82
Fiber	39.35	37.10	37.65	29.98
Starch, sugar, etc	39.65	39.03	37.79	46.10
	100.00	100.00	100.00	100.00

Digestion trials with grain hays have only been conducted in this country with barley and oat hay. On the basis of the results of these trials, and assuming that the digestibility of wheat and rye hays is similar to that of barley hay, the percentage of digestible components in the four kinds of hay are as shown below:

TABLE 19

PERCENTAGE OF DIGESTIBLE COMPONENTS

	Barley	Wheat	Oats	Rye
Digestible protein	4.4	4.3	3.7	3.3
Fiber	18.6	23.0	19.6	24.4
Nitrogen free extract	29.0	24.6	21.2	25.0
Fat	1.7	2.0	3.2	1.8
Total digestible matter	53.7	53.9	47.7	54.5
Nutritive ratio, 1:	11.2	11.5	11.9	15.5

The amounts of digestible components supplied in the hays eaten by the heifers during the progress of the trial have been calculated on basis of the data shown in the preceding table, and are given below. The gains in body weight obtained per 100 lbs. of digestible matter are also given:

TABLE 20

GAINS PER 100 LBS. OF DIGESTIBLE MATTER

	Barley	Wheat	Oats	Rye
Pounds of total digestible matter eaten	3060	3237	2879	2728
Pounds of dry matter per 100 lbs. of gain	13.9	14.9	53.3	14.9

The data given in the table indicate that under the conditions which obtained in these trials there was no marked difference in the nutritive effects of the digestible matter in the three cereals, barley, wheat, and rye, and that the digestible matter of oat hay proved of decidedly lower value than these three cereals for the production of body growth, in the case of heifers experimented with.

General Discussion.—In three different trials with different groups of young dairy stock, and with hays of different origin and quality, the nutritive effect of oat hay fed as sole feed, as in these trials, was found to be considerably lower than that of wheat hay or of the two other cereal hays experimented with. The trials do not furnish any information as to the feeding value or nutritive effects of different grain hays as components of mixed rations, or when fed in connection with one or more feeds of different origin. Extensive investigations with dairy cows have been conducted during the past decade, especially at the Wisconsin Experiment Station,[9] in which the effects of one-sided rations supplied by feeds from a common source have been studied, such as rations composed of feeds derived exclusively

[9] Res. Bul. 17, 49; Jour. Agr. Res. v. 10 (1917) 4, 175.

from the wheat plant, the Indian corn plant, or other single plant sources. In these experiments the corn plant was found to be the only cereal investigated that furnishes feeds which can be fed alone for a long period with satisfactory results as regards the milk production and the continued health or well-being of the cows themselves, or of their offspring.

The animals receiving their nutrients from the oat plant were able to perform all the physiological processes of growth, reproduction, and milk secretion with a certain degree of vigor, but not in the same degree as manifested by the corn-fed animals, while those receiving their nutrients from the wheat plant were unable to perform normally and with vigor all physiological processes. These trials were continued for a series of years, and the results stated did not become apparent until the feeding had been continued for one or more gestation periods.

In these Wisconsin experiments larger gains in body weight were made every year by the animals fed oat feeds than by those receiving wheat feeds, the difference in favor of the former amounting on the average for the three-year period to 22 per cent. The wheat rations fed in the experiments were composed of wheat straw, ground wheat, and wheat gluten, and the oat rations of oat straw and oat meal. The amounts of nutrients furnished and the proportion of the digestible protein to digestible non-protein (nutritive ratio) being the same in all rations fed. Later investigations showed that the relatively poor results obtained with the animals on the sole wheat diet were due to the presence of a toxic principle in the wheat kernel, the cumulative effects of which did not become apparent until the feeding had continued through a full gestation period. The rations made up from the oat plant were found inadequate for efficient nutrition of breeding cows, apparently owing to an insufficient supply of calcium in the ration.

The feeding trials reported in this Californian bulletin were all of relatively short duration, and it cannot be assumed that the results secured under these conditions are attributable to causes that were in operation in the investigation referred to, in which the rations experimented with were fed continuously for a period of several years. They do not therefore throw any light on the question of why the oat hay produced uniformly poorer results as regards gain in body weight than wheat hay, and it must be left to future experiments of a different kind and scope, involving determinations of metabolic processes, to explain the causes of the difference in the results obtained.

SUMMARY

Cereal hay is the most widely grown field crop in California.

Cereal varieties differ as hay crops in production, quality, palatability, chemical composition, physical composition, and nutritive effect.

Barley appeared to be the most valuable hay upon the basis of chemical analysis, but ranked second to wheat in nutritive effect in feeding tests.

Beardless (Nepal) was inferior to other barley varieties in hay yield, palatability, and nutritive effect.

Chevalier barley was superior to other barley varieties in hay yield, palatability, and nutritive effect.

Barley hay suffered less diminution in yield than that of other cereals as a result of drought and late planting.

Wheat, under favorable circumstances, produced higher hay yields than the other cereals, but was less productive than barley under conditions of drought.

Wheat hay fed as an exclusive ration to dairy heifers produced larger gains in body weight per pound fed than barley, oat or rye hay.

Wheat hay, under favorable circumstances, produced more feed value per acre than barley, oat, or rye hay.

White Australian (Pacific Bluestem) proved to be the most prolific hay wheat excepting Velvet Don, but the latter, a typical durum variety, was inferior in palatability and nutritive effect, and unsuited for hay. White Australian also produced the highest gains in body weight per pound fed and per acre of crop. Sonora wheat was less productive, but ranked second to White Australian in food value per acre.

Oat hay proved less nutritious than wheat, barley, or rye hay when fed as an exclusive ration to dairy heifers.

Wild oat hay was less productive, but surpassed cultivated oat hay in palatability and nutritive effect.

The Coastblack oat proved equally productive but less valuable as a hay crop than the California Red oat.

Rye hay was of medium productiveness, but low in palatability and nutritive effect.

The degree of maturity when cut affects the yield, palatability, and the chemical and physical composition of cereal hay.

The highest hay yield for each cereal was obtained by cutting at a stage of development peculiar to itself, and varied for different varieties from "early milk" to "late soft dough."

Immature wheat hay cut in the "blossom" was more palatable to dairy cattle than hay of the same variety cut at later stages of development.

Immature cereal hays are composed of a higher percentage of leaves by weight than mature cereal hays.

Immature cereal hays are richer in proteins and contain less fiber than mature cereal hays.

Experience indicates that barley, wheat and oats should be cut in the "milk" when intended for dairy cattle or saddle horses, and in the "soft dough" when intended for work horses, mules or stock cattle. Rye should be cut in the "blossom" or earlier for all purposes.

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